BUSINESS MODELS FOR SUSTAINABILITY INNOVATION:
CONCEPTUAL FOUNDATIONS AND THE CASE OF SOLAR ENERGY

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Dissertation

accepted by the Faculty of Business and Economics
at Leuphana University of Lüneburg

for the degree of
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by
Florian Lüdeke-Freund (né Lüdeke)

from
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Summary

This dissertation deals with the relationships between the increasingly discussed business model notion, sustainability innovation, and the business case for sustainability concept. The main purpose of this research is to identify and define the so far insufficiently studied theoretical interrelations between these concepts. To this end, according theoretical foundations are developed and combined with empirical studies on selected aspects of the solar photovoltaic industry. This industry is particularly suitable for research on sustainability innovation and business models because of its increasing maturity paired with public policy and market dynamics that lead to a variety of business model-related managerial and entrepreneurial business case challenges. The overarching research question is: *How can business models support the commercialisation of sustainability innovations and thus contribute to business cases for sustainability?*

A theoretical and conceptual foundation is developed based on a systematic literature review on the role of business models in the context of technological, organisational, and social sustainability innovation. Further, the importance of business model innovation is discussed and linked to sustainability strategies and the business case for sustainability concept. These theoretical foundations are applied in an in-depth case study on BP Solar, the former solar photovoltaic subsidiary of British Petroleum. Moreover, because supportive public policies and the availability of financial capital are known to be the most important preconditions for commercial success with innovations such as solar photovoltaic technologies, the solar studies include a comparative multiple-case study on the public policies of China, Germany, and the USA as well as a conjoint experiment to explore debt capital investors' preferences for different types of photovoltaic projects and business models.

As a result, the main contribution of this work is the *business models for sustainability innovation* (BMfSI) framework. This framework is based on the idea that the business model is an artificial and social construct that fulfils different functions resulting from social interaction and their deliberate construction. The BMfSI framework emphasises the so-called mediating function, i.e. the iterative alignment of business model elements with company-internal and external requirements as well as with the specific characteristics of environmentally and socially beneficial innovations. Against this backdrop, it becomes clear that practically-oriented knowledge based on BMfSI research might provide new and effective ways to support the achievement of corporate sustainability.

DISSERTATION CONTENT

A. Dissertation framework

B. Conceptual foundations …

C. … and the case of solar energy

Annex

A. Dissertation framework

I. The business models for sustainability innovation framework

The business models for sustainability innovation framework

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Abstract

This paper develops the *business models for sustainability innovation* (BMfSI) framework. It defines innovation-based business cases as the major goal of sustainable entrepreneurs and identifies their most important barriers, i.e. barriers to profiting from sustainability innovations. A common business model concept is linked to these issues, and its artificial and socially constructed nature, which makes it a multi-functional device, is discussed. Based on these theoretical foundations, the BMfSI framework integrates the main results from the underlying doctoral research project. The framework defines four basic interfaces at the intersections of the most important concepts and issues related to the idea of business models for sustainability innovation: the sustainability innovation, business case, public policy, and financing interfaces. These are connected to the literature in the respective fields and illustrated with findings from different empirical studies on the solar photovoltaic industry. On a general level, the BMfSI framework helps in structuring the emerging sustainable entrepreneurship research with a particular focus on innovation and business models.

Keywords

Business model, sustainability innovation, business case for sustainability, business model for sustainability, framework, solar power, public policy, financing

Lüneburg, 16 August 2013

Content

1 Introduction

1.1 Background

Inventions with the potential to create positive social and ecological effects need to diffuse beyond the niches in which they emerge to become effective sustainability innovations (Geels et al. 2004; Hockerts & Wüstenhagen 2010; Schaltegger & Wagner 2011; Tukker et al. 2008). Sustainable entrepreneurs are faced with this challenge when they try to disseminate new solutions to sustainability problems through commercial activities and aim for large market shares and socio-political influence (Wüstenhagen et al. 2008; Schaltegger 2002; Schaltegger & Wagner 2008). These sustainable innovators tie their business and economic success directly to the achievement of positive effects for humankind and the natural environment (ibid.). However, current research reveals significant uncertainties related to innovation-centric approaches: "Innovation has been widely regarded as a panacea for sustainable development, but there remains considerable uncertainty about how it will lead to a more sustainable society." (Hall & Wagner 2012, p. 183)

The most important uncertainty for sustainable entrepreneurs is whether there will be business cases for their innovations (Schaltegger & Wagner 2011). Depending on personal worldviews as well as organisational and socio-cultural contexts, such business cases can result from financial returns, non-financial effects such as improved reputation, or a "black zero" through the reduction of social and environmental ills (ibid.). No matter what the personal motivations or organisational goals, at one time, sustainable entrepreneurs must commercialise their problem solutions and be successful in mainstream markets to create private and public benefits, i.e. reduce some of the market imperfections and negative externalities that lead to humanity's unsustainable development (Cohen & Winn 2007). Some sustainability thinkers even claim that due to the worsening state of the world, in terms of increasing environmental degradation, poverty, and social injustice, mere reductions of negative effects are insufficient and that instead innovations with "net positive" effects are needed (cf. Ehrenfeld 2008; Ehrenfeld & Hoffman 2013).

Academics and practitioners increasingly discover a management concept that offers alternative approaches to deal with these problems: the *business model.* This concept is changing the management and innovation discourses in remarkable ways: innovations of all kinds are combined with business model thinking to renew and extend common innovation and competitive strategies while diverse intra- and inter-firm issues are addressed (e.g. Casadesus-Masanell & Ricart 2010; Chesbrough 2010; Teece 2010), for example organisational change, value network design, or knowledge and innovation management (e.g. Al-Debei & Avison 2010; Breuer 2013; Morris et al. 2005; Wirtz 2011). The business model also holds the potential to become an innovation itself (e.g. Amit & Zott 2012; Mitchell & Coles 2003). Its main purpose, from a practical perspective, is to allow organisations to create, deliver, and capture value, while management scholars use the business model as an analytical frame and unit of analysis (e.g. Amit & Zott 2001; Seelos 2013).

While the strategy and innovation mainstream treats the business model mainly as a mediator between technologies, strategies, and economic value (e.g. Chesbrough & Rosenbloom 2002; Chesbrough 2010; Hamel 2000; Johnson et al. 2008; Teece 2010), the question of how business models can support sustainable entrepreneurs and their innovations in creating, delivering, and capturing economic, social, and ecological value has so far received little attention. However, some authors have begun to deal with this issue in more detail (e.g. Charter et al. 2008; Johnson & Suskewicz 2009; Lüdeke-Freund 2009, 2010; Stubbs & Cocklin 2008; Wells 2008; Wüstenhagen & Boehnke 2008; Upward 2013).

This dissertation framework paper and the underlying doctoral research seek to contribute to this new scholarly field by exploring the theoretical interrelations between sustainability innovations, business models, and business cases for sustainability. Therefore, this paper outlines a new analytical framework: the *business models for sustainability innovation* (BMfSI) framework whose major purpose is to facilitate research on the above introduced challenge faced by sustainable entrepreneurs. This challenge is rephrased to serve as the overarching research question: *How can business models support the commercialisation of sustainability innovations and thus contribute to business cases for sustainability?*

1.2 Line of reasoning

The BMfSI framework is intended to be an analytical firm-level framework. Different links to the business and socio-political environment are included, but are always seen through the eyes of sustainable entrepreneurs striving for business and economic success (in the widest sense) through the commercialisation of their innovations. The framework does not consider how inventions emerge or how research and development (R&D) are performed. It is assumed that marketable innovations and the desire for commercial success are given.

Under these assumptions, the framework's rationale can be described as follows: sustainable entrepreneurs, as defined by Schaltegger and Wagner (2008, 2011) and Hockerts and

Wüstenhagen (2010), pursue corporate sustainability mainly through the creation of so-called business cases for sustainability (Schaltegger & Wagner 2006; Schaltegger & Burrit 2005). Innovation, including new processes, products, and organisational forms, is widely discussed as a strategy to create such business cases (Schaltegger & Wagner 2011; Wüstenhagen et al. 2008; Hockerts & Wüstenhagen 2010). While the innovation potential of the business model has been recognised for about fifteen years in mainstream management research (e.g. Hamel 2000; Chesbrough & Rosenbloom 2002; Linder & Cantrell 2000), it has hardly been investigated from a corporate sustainability or sustainable entrepreneurship perspective (Boons & Lüdeke-Freund 2013; Lüdeke-Freund 2009). Therefore, the BMfSI framework is based on the assumption that business models, i.e. particular business model *functions,* can support the commercialisation of sustainability innovations, which is assumed to be a promising, yet neglected way to create and extend business case for sustainability opportunities (Schaltegger et al. 2012). Figure 1 summarises this line of reasoning.

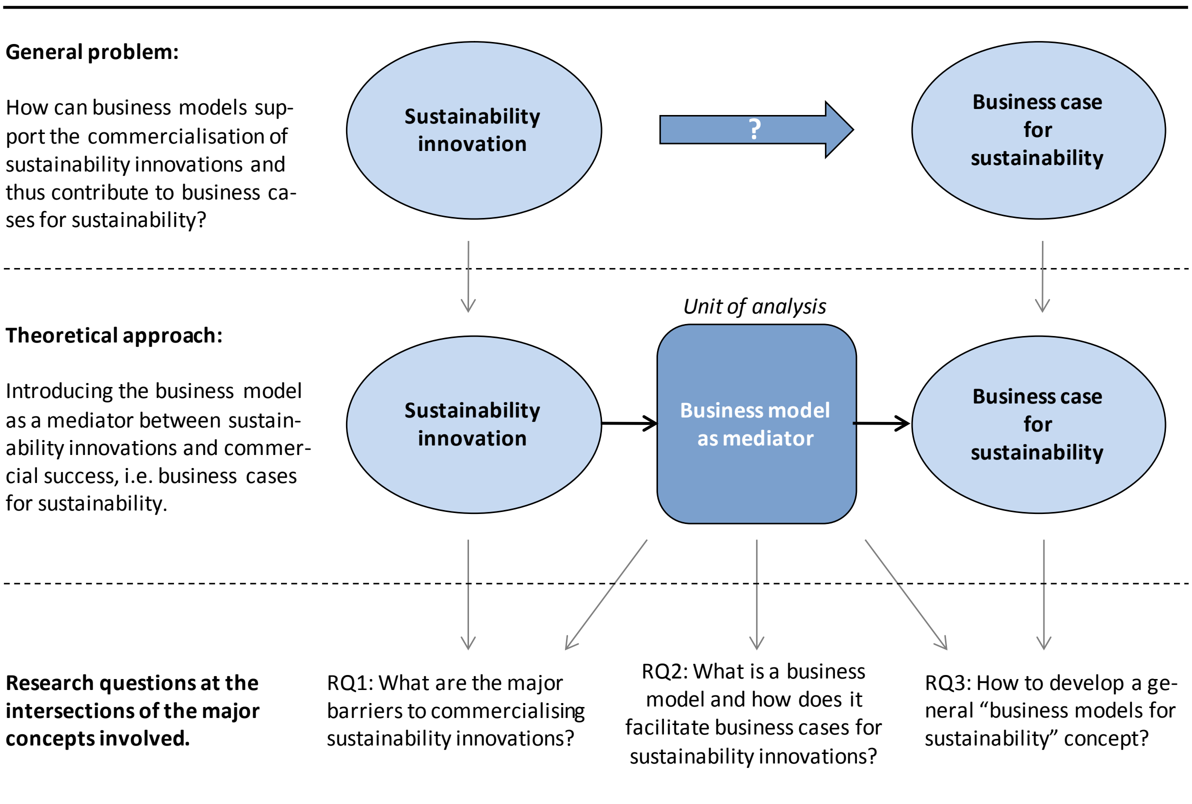

Figure 1: Line of reasoning for developing the BMfSI framework

Starting from the challenge of commercialising sustainability innovations, the business model is introduced as a mediator between innovations and business cases, according to widely accepted business model interpretations as a "focusing device" that mediates between technologies and value creation (Chesbrough & Rosenbloom 2002) or a "market device" that facilitates the development of value networks and markets for new ventures (Doganova & Eyquem-Renault 2009). Figure 1 identifies more detailed research questions which emerge at the intersections of the major concepts involved and that can be used to further operationalise the overarching research question:

(1) *What are the major barriers to commercialising sustainability innovations?*
(2) *What is a business model, and how does it facilitate business cases for sustainability innovations?*
(3) *How do answers to these questions support the development of a general "business models for sustainability" concept?*

A framework that integrates these questions has to merge different theoretical foundations, ranging from sustainable entrepreneurship to innovation management and business model basics. Therefore, Section 2 introduces the business case for sustainability as the major goal of sustainable entrepreneurship (Section 2.1), discusses barriers to profiting from sustainability innovation (Section 2.2), and, finally, describes the business model concept in more detail and explains its artificial and socially constructed nature that makes it a device with particularly assigned functions (Section 2.3). Section 3 introduces the BMfSI framework which is then used to summarise and discuss the major results from the underlying doctoral research project. Section 4 summarises the essence of this framework paper by answering the above formulated three questions. Section 5 points to limitations and future research.

2 Literature review and theoretical foundations

2.1 From sustainable entrepreneurship to business models for sustainability

2.1.1 Sustainable entrepreneurship and business cases for sustainability

Hockerts and Wüstenhagen (2010) define *sustainable entrepreneurship* as "the discovery and exploitation of economic opportunities through the generation of market disequilibria that initiate the transformation of a sector towards an environmentally and socially more sustainable state" (ibid., p. 482), and they use the term "to describe activities by small or large firms that represent disruptive, rather than incremental innovation" (ibid., p. 483). The authors use the "Emerging Davids" and "Greening Goliaths" analogy to distinguish different ideal-typical approaches to the development and dissemination of sustainable products and services. With regard to the magnitude of market and socio-political effects of sustainable entrepreneurship, Schaltegger and Wagner (2008, 2011) propose a matrix of administrative, managerial, and entrepreneurial approaches which differ as to how deep the solution of sustainability problems is embedded within a firm's core business (cf. Schaltegger 2002, 2005). The Emerging Davids and Greening Goliaths analogy and the sustainable entrepreneurship matrix are different in that the former focuses on the mutually reinforcing processes between small/new and large/incumbent firms, while the latter identifies the detailed characteristics of different forms of sustainable entrepreneurship. However, both agree on the pivotal role of sustainability innovation for primarily business-based (as opposed to primarily regulation-based) industry transformations, which result from market disequilibria (Hockert & Wüstenhagen 2010) created by sustainable entrepreneurs and corporate sustainability managers (Schaltegger & Wagner 2011) who use their core businesses to convert market imperfections into business opportunities (Cohen & Winn 2007).

Discovering and exploiting such opportunities should, in theory, allow sustainable entrepreneurs to realise *business cases for sustainability* (Schaltegger & Wagner 2006). In essence, business cases for sustainability are based on the creation and management of positive interrelations between economic and business success as well as contributions to a sustainable development of the economy and society (e.g. Epstein & Roy 2003; Dyllick & Hockerts 2002; Salzmann et al. 2005; Steger 2006). On this view, business cases for sustainability innovation must be built on a voluntary basis, have positive social, environmental, and business effects and must be based on distinct decisions and activities, i.e. they should not emerge accidentally (cf. Schaltegger & Lüdeke-Freund 2013). Assuming that radical innovations are crucial for improving a firm's sustainability performance (without neglecting the effects of accumulated incremental measures), the theoretical relationships between a firm's economic success and social and/or ecological performance of its cumulated sustainability innovations can be illustrated as in Figure 2. The economically optimal business case is achieved at point A (ES*/ESP*). Beyond this point, i.e. towards points B and C, trade-offs occur and the economic performance decreases because of rising marginal costs of further sustainability innovations after the "low hanging fruits" have been picked (cf. Hahn et al. 2010; Lankoski 2006). A socially or ecologically optimal business case would be slightly above point B (ES_0/ESP_1). However, even if profitable innovations exist, the economic performance will at some point have its culmination and decline.

Besides this *revisionist view,* which accepts the existence of (limited) win-win situations (curve ES_0-A-B-C), the *traditionalist view* sees only trade-offs as soon as a company goes beyond the legally required minimum, which corresponds to curve ES_0-E-F-D (for a detailed discussion see Schaltegger & Burritt 2005; Schaltegger & Wagner 2006).

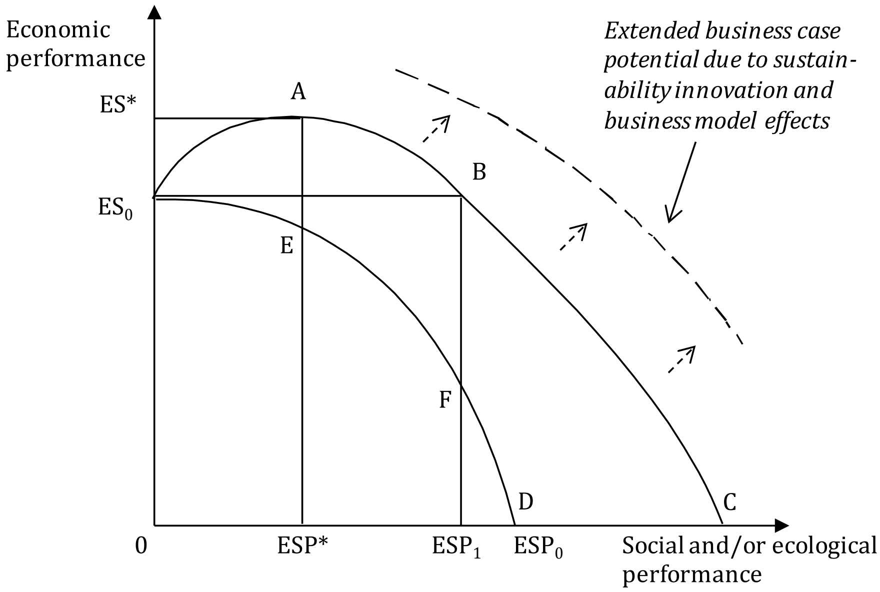

Figure 2: Relationships of economic and social and/or ecological performance (adapted from Schaltegger & Synnestvedt 2002; Schaltegger & Burritt 2005)

In line with Chesbrough and Rosenbloom's (2002) findings on the cognitive effects of business models on value creation from new technologies, one can assume that sustainability innovations together with managed business models and business model innovation can extend given and create new business case opportunities – indicated by the dashed line in the upper right of Figure 2 (Schaltegger et al. 2012).

2.1.2 Towards business models for sustainability

The thesis that business models can support corporate sustainability was explicitly formulated in the course of the last seven or eight years (cf. Charter et al. 2008; Lüdeke-Freund 2009, 2010; Stubbs & Cocklin 2008; Tukker et al. 2006; Wells 2008; Wells & Seitz 2005; Wüstenhagen & Boehnke 2008), while earlier but less explicit ideas can be tracked back more than fifteen years (e.g. Elkington 2001; Hart 1997; Lovins et al. 1999). However, the development of rigorous theoretical concepts and empirical research is still in the very beginning stages. Interestingly, the most focused work can be found in doctoral theses, for example on marketing micro cogeneration technologies (Boehnke 2008), renewable energy finance (Loock 2010), energy service companies (Hannon 2012), or strategic poverty alleviation (Klein 2008). However, a more general understanding of business models for sustainability is still missing due to these works' issue and industry orientation. An exception is the radical work of Upward (2013) who developed a "strongly sustainable business model ontology" (SSBMO) and "canvas" (SSBMC) by combining Osterwalder and Pigneur's (2010) concept with an extensive review of the current knowledge from the natural and social sustainability sciences. Explicit links between the SSBM approach and sustainable entrepreneurship and corporate sustainability management are under development.

At the outset of the sustainable business model discourse, Charter et al. (2008) outlined some of the major topics to be considered. The authors argue that sustainable patterns of consumption and production require radical and sustainability-driven innovations, which, however, mostly start in niches and struggle to reach mainstream markets (cf. Tukker et al. 2008). They saw that by "designing the elements of value proposition, value creation and revenue delivery appropriately a firm can tune its offering, although the challenge is to develop a business model that is environmentally, socially and economically sustainable" (Charter et al. 2008, p. 59). Developing sustainable business models, in their view, is a question of new organisational structures, new offerings like product-service systems, and alleviating poverty through business development at "the bottom of the pyramid", while major barriers are financial shareholders' dominance, problems in identifying sustainable business opportunities, and lock-in effects due to the need to protect established brands.

In parallel, Stubbs and Cocklin (2008) published their "sustainability business model" ideal type. They address some of the aspects mentioned by Charter et al. (2008), whereas their focus is on normative principles of organisational development. Stubbs and Cockling pioneered the field of empirical research on sustainable business models and case-based theory building, using the cases of Interface Inc. and Bendigo Bank. Their work reveals the complexities of unfolding and representing the embeddedness of sustainability principles within organisations. However, they managed to develop their ideal type by defining structural and cultural attributes relating to the internal capabilities and external socio-economic environment of an organisation, such as community spirit (cultural/external), employees' trust and loyalty (cultural/internal), or sustainability reporting (structural/internal) (Stubbs & Cocklin 2008, pp. 113-114). Moreover, five propositions about sustainable organisations are proposed, including a business purpose definition that integrates social, ecological and financial goals, accordingly designed performance measurement systems, and leaders who stimulate cultural and structural changes.

Combining the main findings from the available literature reveals that the business model is seen as both a supporting device, as suggested by Charter et al. (2008), and as an object of innovation, as suggested by Stubbs and Cocklin (2008) (see also Boons et al. 2013; Beltramello et al. 2013; Bisgaard et al. 2012). Regardless of how compelling these theoretical perspectives may be, in the end, the question arises whether sustainable entrepreneurs can develop and manage their business models in a way that allows them to profit (in the widest sense) from their innovations. This in turn requires identifying the barriers to commercialising and profiting from sustainability innovations (cf. RQ1 in Figure 1).

2.2 Profiting from sustainability innovation

2.2.1 Teecian innovation challenges

The commercialisation of innovations, be it mainstream consumables like Smartphones or radical system innovations like an e-mobility infrastructure, confronts innovators with diverse challenges, from identifying customer segments and their needs to production upscaling and capturing a "fair" share of the profits. In this context, Teece identified a fundamental dilemma: it is often *not* the innovator, i.e. the first mover who introduces a new process, product, or service, who profits most from an innovation, but suppliers, cooperators, customers, and competitors (Teece 1986; see also Chesbrough 2010). Teece developed the "profiting from innovation" (PFI) framework to explain how strategic positioning together with internal (e.g. the innovator's asset structure) and external (e.g. the number of suppliers) factors influence the ability to capture value from an innovation (Teece 1986, 2006).

The PFI framework contains three building blocks to analyse and predict commercialisation success (Teece 1986, p. 286-290). The *appropriability regime* describes how the type of innovation and the available forms of intellectual property protection determine the likelihood of capturing value from an innovation. Teece distinguishes tight regimes, e.g. hard to imitate, patent-protected chemical processes, from weak regimes, e.g. manufacturing processes that can be copied without defying copyrights or trade secrets. *Dominant designs* are product layouts or production processes that serve as official or quasi industry standard. In the early phase of an industry, competition is about design sovereignty since the owner of a dominant design can achieve a superior market position against competitors. When a dominant design has emerged, competition is about learning, production costs, and the optimal employment of specialised capital. Specialised assets and capabilities are central to the *complementary assets* concept, the third PFI building block. Teece argues that the successful commercialisation of innovations depends in most cases on assets and capabilities of third parties, e.g. marketing and after-sales services or low-cost manufacturing, but also complementary products or services in the case of more systemic innovations (cf. Andersen 2008).

While these "Teecian" challenges can be regarded as universally valid, profiting from sustainability innovation is confronted with specific problems resulting from the deliberate aspiration to co-create economic, social and ecological value (cf. Boons 2009; Boons et al. 2013; Cohen & Winn 2007; Hansen et al. 2009; Hockerts & Wüstenhagen 2010).

2.2.2 Sustainability innovation challenges

Based on Charter and Clark (2007), Boons et al. (2013) define sustainable innovation as "a process where sustainability considerations (environmental, social, and financial) are integrated into company systems from idea generation through to research and development (R&D) and commercialization" (ibid., p. 3). The results of such processes are new technologies, products, and services as well as business and organizational models, i.e. distinct sustainability innovations, with improved performance, "where such performance includes ecological, economic, and social criteria" (ibid., p. 2; see also Carrillo-Hermosilla 2010). With regard to outcomes, Hansen et al. (2009) posit that "sustainability innovations are innovations which maintain or increase the overall capital stock (economic, environmental, social) of a company" (ibid., p. 686), which means that sustainable entrepreneurs not only have to internalise negative external effects with their innovations (Cohen & Winn 2007; Schaltegger & Wagner 2011), but should also try to produce "net positive" effects (Ehrenfeld 2008).

Besides material problems such as cost disadvantages from the deliberate internalisation of societal costs and the multi-dimensionality of socio-ecological problems (Fichter 2005), the concept of sustainability innovation itself is problematic: with regard to balancing the multiple interests that converge on this notion, Hansen et al. (2009) argue that "[a]ggregating economic, ecological and social effects inevitably leads to trade-offs and is limited due to current methodological constraints … [and that] objective and specific 'labelling' of innovations as being sustainable can only be achieved within a collective and social discourse" (p. 687). As an example, while the majority of potential customers should be able to agree on the most comfortable Smartphone, achieving agreement on the most sustainable one would be much more difficult. Boons et al. (2013) frame this problem as spatial, temporal, and cultural embeddedness, which leads to different context-specific meanings of sustainable development and sustainability (see also Boons & Mendoza 2010; Lüdeke-Freund et al. 2012b). Moreover, despite the commonly presumed business opportunities (e.g. Charter & Tischner 2001; Tukker & Tischner 2006), Hansen et al. (2009) point out that only a minority of companies do initiate sustainability innovation processes. They explain this reluctance with higher-than-average risks that go beyond economic uncertainties and include so-called directional risks (Paech 2005). These imply that the direction of innovation impacts, i.e. positive or negative social and/or ecological effects, cannot be anticipated. Therefore, Hansen and colleagues introduce the concept of sustainability-oriented innovations: "In this regard, the term 'sustainability-*oriented* innovation' (SOI) emphasizes that sustainability is not an end point but rather a (normative) direction which is linked to (directional) risks." (Hansen & Große-Dunker 2013, p. 2408; original italics)

Furthermore, it is commonly assumed that sustainability innovations must be rather radical and systemic to change existing patterns of production and consumption (e.g. Boons et al. 2013; Hansen et al. 2009; Schaltegger & Wagner 2011; Schaltegger et al. 2012; Wüstenhagen et al. 2008). The literature on sustainability transitions emphasises these characteristics as important for breaking dominant technological regimes, though the accumulation of incremental changes is also seen as a transformative force (e.g. Andersen 2008; Berkhout et al. 2004; Geels 2004). Widely discussed examples of such innovations are product-service systems. These include approaches like using instead of buying products (e.g. car sharing), dematerialisation through increased services (e.g. washing centres), leasing models (e.g. chemical leasing), or repairing instead of throwing away (e.g. maintenance and refitting of white goods) (cf. Charter & Tischner 2001; Mont 2002; Mont & Emtairah 2008; Tukker & Tischner 2006). However, despite the theoretically persuasive advantages of radical and systemic innovations, Andersen (2008) adds for consideration that their problem-solving potential should not be overestimated since convincing correlations between innovation type and sustainability performance are rare.

Finally, the most denoting challenge is the so-called double externality problem (Rennings 2000). Innovation economics deals with spillover effects from R&D which allow third parties to profit from an innovator's activities "for free", for example through unavoidable (or intended) knowledge transfer or the dependency on complementary assets owned by others (cf. Teece 1986, 2006). Additionally, environmental economics is concerned with negative external effects resulting from insufficient reflection, i.e. internalisation, of the costs associated with ecological damages (cf. Cohen & Winn 2007; Rennings 2000). These costs, including those related to social impacts, are deliberately internalised, as far as possible, by sustainable entrepreneurs and their innovations. The double externality problem means that part of the value of an innovation cannot be appropriated due to innovation spillovers, while at the same time external costs are borne by the innovator (Hockerts & Wüstenhagen 2010).

Challenges relate to ...	Description of major challenges
Teecian challenges of "profiting from innovation"	
Appropriability regime	Type of innovation (e.g. product), knowledge (e.g. tacit), and protection (e.g. patents) determine the ability to capture value from an innovation -> Identify most advantageous regime
Dominant design	In early industry phases innovators compete about standards, i.e. dominating product and process designs -> Strive for owning a dominant design or complementary assets for it
Complementary assets	Innovations depend on generic or (co-)specialized assets and capabilities of others (whereas these assets can also depend on the innovation) -> Identify an advantageous position towards asset and capability owners
Further challenges of "profiting from sustainability innovation"	
Discursive ambiguity	The meaning of sustainable development and sustainability is spatially, temporally, and culturally embedded -> Specify in what respect an innovation is "sustainable"
Methodological constraints	Lack of (trusted) methods to prove the sustainability of an innovation, e.g. accounting systems, performance measurement, and communication -> Make assessment methods and methodological flaws transparent
Directional risks	The social, ecological, and economic effects of an innovation cannot not (or only insufficiently) be anticipated -> Avoid early lock-ins and monitor progress towards agreed-on goals
Radical innovation	Technological regimes and unsustainable dominant designs must be replaced by radical innovations; these are mostly developed in niches -> Aim for co-evolution of Davids and Goliaths; use transformative power of accumulated incremental steps
System-level change	Besides radical changes, system-level changes are required to transform technological regimes and currently dominating designs -> Create transformation path by involving multiple artefacts and actors
Double externality problem	Innovation spillovers and the internalisation of external costs are a double burden for sustainable entrepreneurs -> Exploit and lobby for public sustainability policies; sensitize customers

Table 1: Challenges of profiting from sustainability innovation

To sum up, profiting from sustainability innovation confronts sustainable entrepreneurs with the general Teecian challenges described in the PFI framework (Teece 1986, 2006) as well as further barriers resulting from the aspiration to create positive social and ecological effects. Table 1 summarizes these challenges.

With regard to the Teecian challenges of appropriating economic value from innovation, a plethora of reasons for dealing with business models and business model innovation can be found in the literature (e.g. in a Long Range Planning special issue, 2010, Vol. 43, No. 2/3, or two Harvard Business Review collections published in 2010 and 2011). Chesbrough boils it down: "The economic value of a technology remains latent until it is commercialized in some way via a business model. The same technology commercialized in two different ways will yield two different returns." (Chesbrough 2010, p. 354) Going beyond economic value and technological innovation in a narrow sense, the question is what is a business model and how can it unlock and leverage the latent sustainability potential of an innovation, i.e. how does it mediate between sustainability innovations and business cases for sustainability (cf. RQ2 in Figure 1).

2.3 The business model as mediating construct

2.3.1 The business model concept

The business model is a rather young concept which emerged around fifteen years ago as an explicitly defined notion. It is since then becoming increasingly established in research and practice (e.g. Baden-Fuller et al. 2010; Wirtz 2011). Most publications relate its emergence to the dot-com hype, i.e. the new economy and "e"-era (e.g. Timmers 1998). However, influential works simultaneously emerged in the strategy and innovation domains (e.g. Hamel 2000; Linder & Cantrell 2000; Magretta 2002). At these times, business model concepts and research topics were rather limited, whereas today the amount of peer-reviewed scientific journal articles containing "business model" has grown to 8,464 in EBSCO's Business Source Premier alone (as of 13 June 2013). Al-Debei and Avison (2010), for example, compare 20 different scholarly definitions and Wirtz (2011) provides a 70-page overview covering the period from 1975 to 2010. With regard to single concepts, the ones developed by Osterwalder and Pigneur (Osterwalder et al. 2005; Osterwalder & Pigneur 2010) and Johnson (Johnson et al. 2008; Johnson 2010) are widely accepted (in terms of citations) and provide some coherence across disciplinary and research-practice boundaries. With regard to theory development, the works of Amit and Zott, Chesbrough or Teece often serve as reference points (e.g. Amit & Zott 2001; Zott & Amit 2007, 2008; Chesbrough & Rosenbloom 2002; Chesbrough 2010; Teece 2010).

To introduce the business model on a general level, the definition given in Teece (2010) is used (see also Teece 2006): "A business model describes the design or architecture of the value creation, delivery and capture mechanisms employed. The essence of a business model is that it crystallizes customer needs and ability to pay, defines the manner by which the business enterprise responds to and delivers value to customers, entices customers to pay for value, and converts those payments to profit through the proper design and operation of the various elements of the value chain." (Teece 2010, p. 179)

This definition highlights functions mainly discussed by strategy and innovation scholars: creating, delivering, and capturing value (e.g. Afuah 2004; Chesbrough & Rosenbloom 2002; Chesbrough 2010; Hamel 2000; Johnson 2010; Linder & Cantrell 2000; Magretta 2002; Shafer et al. 2005; Wirtz et al. 2010; Zott & Amit 2010). Besides these value-related functions, Osterwalder defined further strategic, conceptual, and operational functions, "which are understanding and sharing, analyzing, managing, prospects and patenting of business models" (Osterwalder 2004, p. 19; see also Al-Debei & Avison 2010).

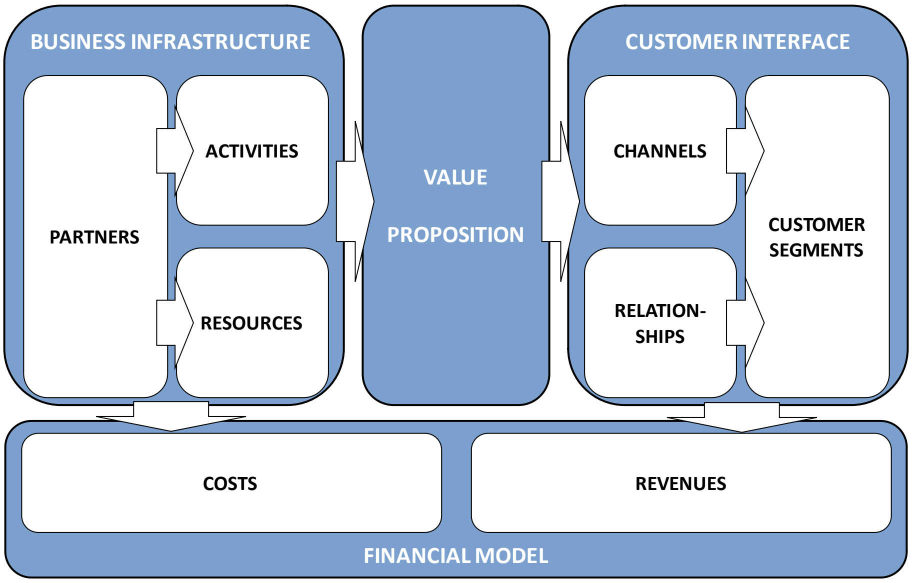

Figure 3: Visual representation according to the "business model canvas" (adapted from Osterwalder & Pigneur 2010, and www.businessmodelgeneration.com)

A variety of visual concepts have been developed to support these functions and represent business models (e.g. Breuer 2013), often inspired by Osterwalder's (2004) "business model ontology" and "canvas" (popularised in Osterwalder & Pigneur 2010 [first edition 2009]). The canvas combines four main pillars (Figure 3): any business model focuses on the *value proposition* for its customers. Therefore, the *business infrastructure* combines own and third-party activities and resources to develop competitive value propositions, i.e. products and services. To offer these to target customer segments, the *customer interface* establishes communication and distribution channels as well as customer relationships. Finally, the *financial model* optimises the costs incurred by the business infrastructure and the revenues from the customer interface to appropriate economic value for the company. This view resonates with Teece's definition and its emphasis on value creation, delivery, and capture.

Teece (2010) furthermore discusses functions related to the commercialisation of innovations, which are, in his view, neglected in standard economic theory: he questions the assumption that innovations enable companies to create value by some kind of automatism. He also scrutinizes that offerings create customer value per se since neither markets nor a willingness to pay can be presumed. He concludes that commercialising innovations, which often requires the creation of new markets and stimulation of willingness to pay, is a business model task. In analogy, bringing socially and environmentally beneficial products, services, or product-service-systems to market is not a process regulated by supply and demand structures or public policies alone. It is also a question of business models (cf. Boons et al. 2013; Charter et al. 2008; Schaltegger et al. 2012; Tukker et al. 2006).

2.3.2 Understanding the "business-model-as-construct"

The business model is mostly referred to as a concept (e.g. Amit & Zott 2001; Baden-Fuller & Morgan 2010; Hedman & Kalling 2003; Schweizer 2005; Teece 2010; Zott et al. 2011), i.e. a logical and abstract idea that supports higher-level thinking, or as a framework (e.g. Al-Debei & Avison 2010; Chesbrough & Rosenbloom 2002; Lambert 2010; Wirtz 2011), i.e. a reference system that combines different concepts and their (causal) relationships. As a concept or framework it has different model characteristics and functions which allow researchers and practitioners to define and deal with chosen aspects of business reality (Baden-Fuller & Morgan 2010; Seelos 2013). The business model is a good example of both the dominant functionalist and constructivist stances in management practice and research (cf. Samra-Fredericks 2008). A common approach to capture the desired aspects, such as the offerings, underlying processes, and value creation logic of a company, is to define the constituting business model elements and their relationships (for overviews see e.g. Al-Debei & Avison 2010; Morris et al. 2005; Shafer et al. 2005; Wirtz 2011), i.e. to create some form of representing construct. Therefore, the business model can basically be understood as an artificial construct which can assume the form of a verbal definition, diagram, concept, or more complex framework.

Disciplines like philosophy of science deal with constructivism, also referred to as constructionism, as a way of thinking about natural and social objects (cf. Mallon 2008; Samra-Fredericks 2008; Searle 1995). Fletcher (2006), building on Berger and Luckmann (1967), introduces the term social construction as meaning the "shared processes and negotiated understandings in which people engage to create meaning" (p. 426). And Mallon (2008) states "that the core idea of constructionism is that some social agent produces or controls some object … [by] intentional activity, engaged in step-by-step fashion, producing a designed, artifactual product" (p. 5). Central to the constructivist view are shared processes of sense-making and the relationships between objects, for example a company, and the constructs derived from these objects, for example the role of a CEO (social construct) or a balance sheet (artifactual construct).

The business model is such a *socio-artificial construct* that "must be represented for being analyzed and evaluated" (Sánchez & Ricart 2010, p. 139). It is derived and merged from different organisational, technological, and social objects within an organisation and its environment. The "business-model-as-construct" (hyphenated to tie it directly to its artificial nature) depends on a constitutive relationship between social agents who deal with it, for example product developers and marketing experts, and the constructs and representations they use to facilitate their social interaction (cf. Mallon 2008). It follows that creating and sharing constructs and representations of business models is equivalent to their constitution. Otherwise, they would remain pure mental models in social agents' minds without any potential for real impacts (cf. Doganova & Eyquem-Renault 2009; Osterwalder 2004).

This business-model-as-construct view is different from perspectives that refer to "real" and implemented business models (in the sense of "operating models"; Linder & Cantrell 2000). As an example, the statement that a business model *has* a particular function can be interpreted in different ways: on the empirical level an operating business model can show this function, while on the construct level this function has to be attributed to an artificial business model representation by means of logical reasoning and social sense-making (cf. Searle 1995). Of course, these views interrelate as empirically observed functions can lead to new construct functions (and vice versa), but drawing this distinction is important since only the business-model-as-construct and its socio-artificial qualities allow for the assignment of, and agreement on, functions like value creation or innovation support. Without such assignments and agreements the business model would be nothing but an arbitrary compilation of organisational properties.

2.3.3 The business model's mediating function

A crucial function assigned to the business model in nearly all domains, technology-, organisation-, and strategy-oriented, can be described as alignment or (inter-)mediation (cf. Al-Debei & Avison 2010; Chesbrough & Rosenbloom 2002; Lambert 2010). This function mediates between different parts and facets of an organisation, the technologies (in a wider sense, innovations) it employs and its environment: "The business model concept helps ameliorating the design, planning, changing and implementation of business models. Additionally, with a business model approach companies can react faster to changes in the business environment. Finally, the business model concept improves the alignment of strategy, business organization and technology." (Osterwalder 2004, p. 21) Al-Debei and Avison (2010) call it accordingly an "alignment instrument" and "intermediate theoretical layer". They find that "business strategy, BM [business model], and business processes along with their IS [information systems], should be treated as a harmonized package. This package should be reviewed continually to ensure its consistency with the external environment as well as the stakeholders' interests" (Al-Debei & Avison 2010, p. 371). These and further authors assign a *mediating function* to the business model that spans different organisational layers and perspectives and also enables alignment with the external business environment.

The most prominent description of this function can be found in Chesbrough and Rosenbloom's (2002) seminal article on Xerox Corporation's technology spin-offs, in which they studied the business model's cognitive implications for commercialisation success and failure when it comes to new technologies that do not fit with the dominant business logic of an innovating firm. They find that "[t]he business model provides a coherent framework that takes technological characteristics and potentials as inputs, and converts them through customers and markets into economic outputs. The business model is thus conceived as a focusing device that mediates between technology development and economic value creation" (Chesbrough & Rosenbloom 2002, p. 532). Figure 4 illustrates this view.

Chesbrough and Rosenbloom describe the mediating function as an iterative alignment of the characteristics of a technology and the business model elements needed for its commercialisation, ranging from the definition of value propositions and respective market segments to positioning the firm in the supply chain and overarching value network (Chesbrough & Rosenbloom 2002, pp. 533-536). Moreover, further functions are mentioned, like securing a share of the technology's economic value, in the sense of Teece's (1986, 2006) value appropriation strategies, and determining the financial needs to implement market and upscaling strategies (see also Teece 2010).

While mainstream technology entrepreneurs use their business models to optimise the ratio of technical inputs and economic outputs, sustainable entrepreneurs aim for multiple outcomes in terms of solutions to social and ecological problems, whereas they are often faced with limited input availability. For example, bio-pioneers (Schaltegger 2002) of organic textiles had to develop new supply chains to gain access to alternative feedstock sources, manufacturing capacities, and management competencies (Hansen & Schaltegger 2013). And social entrepreneurs in developing countries are faced with diverse scarcities such as a lack of production inputs, business competencies, or institutional settings (Sánchez & Ricart 2010; Seelos & Mair 2005, 2007; Seelos 2013). Such context-specific problems add to the above compiled general challenges of profiting from sustainability innovation (Section 2.2.2; Table 1).

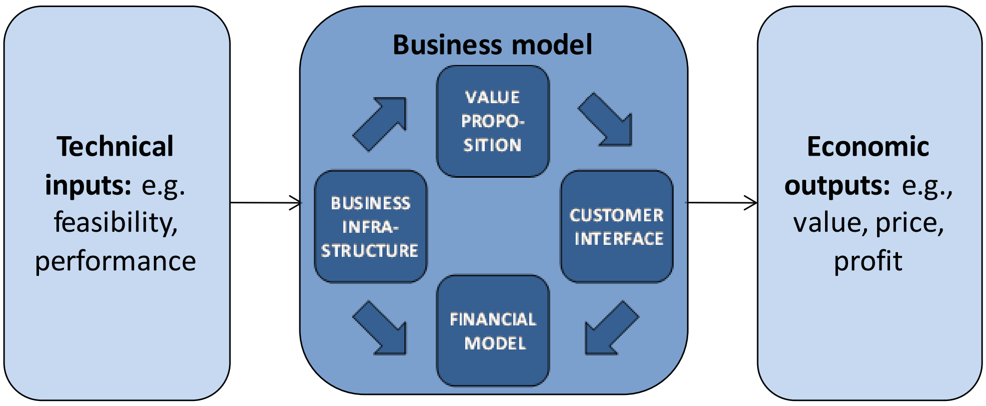

Figure 4: The business model as mediator between technical and economic domains (adapted from Chesbrough & Rosenbloom 2002; Osterwalder & Pigneur 2010)[1]

To clarify the mediating role of the business model in the context of sustainability innovation and corporate sustainability, the next section introduces the BMfSI framework and reflects on the main findings from the underlying doctoral research project. This framework might serve as a starting point for the future development of a general "business models for sustainability" concept (cf. RQ3 in Figure 1).

[1] The original illustration by Chesbrough and Rosenbloom (2002) contains a list of six business model elements (market, value proposition, value chain, cost and profit, value network, competitive strategy) instead of a visual representation. The representation used here is based on the four main pillars of Osterwalder and Pigneur's (2010) business model concept (Section 2.3.1).

3 The business models for sustainability innovation framework

3.1 Introduction to the framework

The *business models for sustainability innovation* (BMfSI) framework and the associated publications (see Annex) are built upon the business-model-as-construct and its mediating function, comparable to Amit and Zott's (2001) "unifying unit of analysis" or Seelos's (2013) "analytical device". As described in Section 1.2, the framework primarily serves theoretical and research purposes. It is not meant to be a tool for applied business model management, i.e. the practical design, implementation, or improvement of operating models. Moreover, it does not explicitly take idea generation (i.e. inventions) and R&D activities into consideration since the existence of marketable innovations and commercial ambitions are presupposed. The value of this framework lies rather in its generic quality and the *horizontally and vertically structured relationships* between the different concepts of innovation, business model, and corporate sustainability research.

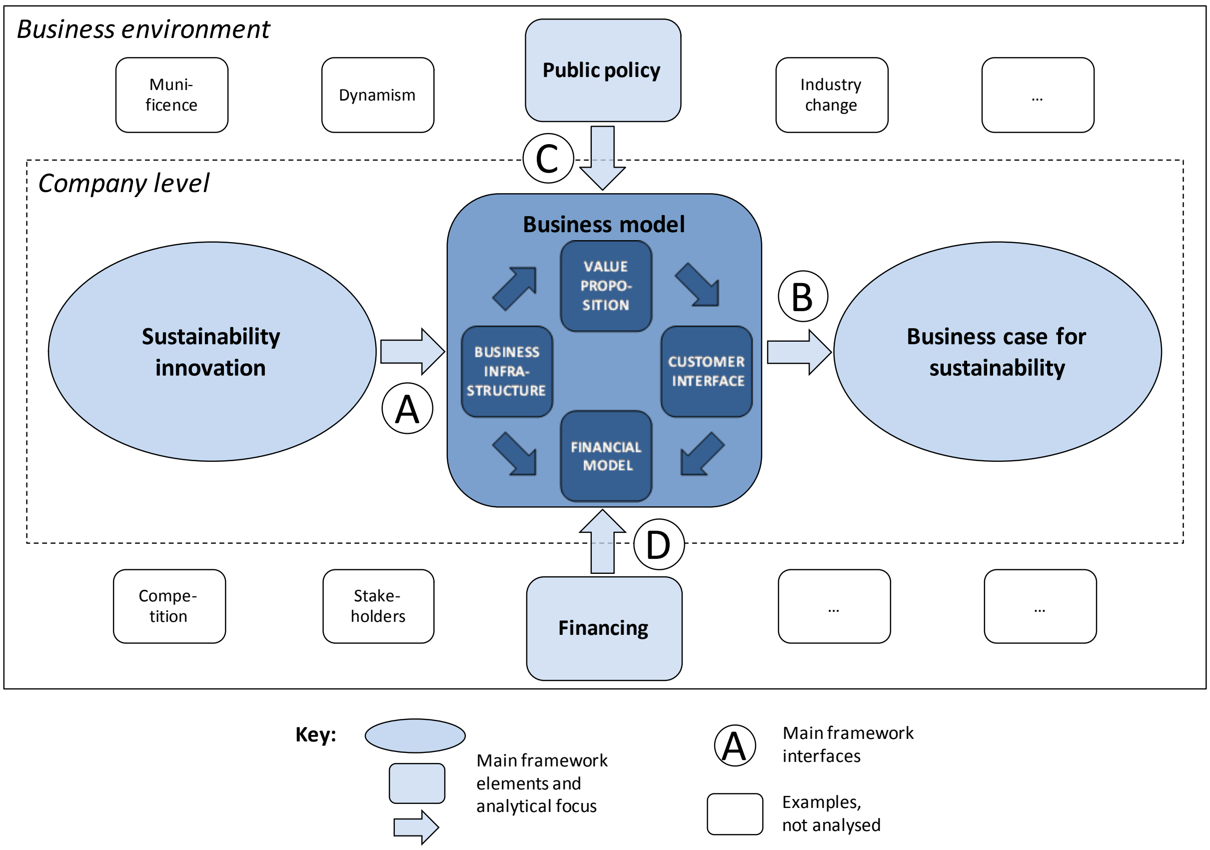

Figure 5: The business models for sustainability innovation framework

The *horizontal main axis* connects the three major concepts outlined in Sections 2.1 to 2.3 and describes the following scenario: sustainable entrepreneurs pursue corporate sustainability mainly through the creation of business cases for sustainability (right-hand side of Figure 5). Sustainability innovation is seen as a major approach in creating business cases (left-hand side of Figure 5). The framework is based on the assumption that the assigned mediating function of the business model can support the commercialisation of sustainability innovations (centre of Figure 5), which is expected to be a pivotal strategy to create and extend innovation-based business case opportunities (Section 2.1.1, Figure 2) (cf. Schaltegger & Wagner 2008, 2011).

The *vertical main axis* connects the company level with the external business environment. The dashed line indicates that a strict separation between these two levels is impossible due to various overlaps and exchange relationships (e.g. with suppliers, competitors and further stakeholders, regulatory influences, and dependencies on complementary assets) as well as the fact that corporate sustainability activities are by definition not limited to the company level. Sustainability innovations and business cases for sustainability are expected to unfold effects beyond corporate boundaries. However, for reasons of analytical clarity, the three major concepts constituting the horizontal axis of the BMfSI framework are assigned to the company level where they are primarily managed.

When describing the business model's mediating function, many authors point to the importance of company-environment relationships (Section 2.3.3) (cf. Al-Debei & Avison 2010; Chesbrough & Rosenbloom 2002; Osterwalder 2004). Figure 5 highlights two aspects from the business environment: the critical role of public policies and financing for sustainable entrepreneurs and their innovations (cf. Boons et al. 2013; Cohen & Winn 2007; Hockerts & Wüstenhagen 2010; Rennings 2000). While the business environment exerts influence in a lot more ways, e.g. through market competition, industry dynamics and trends, or its overall munificence (cf. Sánchez & Ricart 2010), supportive public policies and the availability of financial capital are two crucial preconditions for commercial success with sustainability innovations (besides sufficient demand side potential), as shown for example by a wide range of studies on renewable energy technologies (e.g. Murphy & Edwards 2003; Grubb 2004; Hampl 2012; Loock 2010; Nemet 2009; Wüstenhagen & Menichetti 2012) and a recent OECD study on new business models for "green growth" (Beltramello et al. 2013; see also Bisgaard et al. 2012).

Figure 5 defines four main framework interfaces, two of which should be relevant for most research on sustainability innovation, business models, and business cases: the *sustainabil-*

ity innovation and *business case for sustainability interfaces* (A and B in Figure 5). The *public policy* and *financing interfaces* (C and D in Figure 5) were chosen due to their fundamental relevance (see above). However, the definition of company-environment relationships also depends on individual research interests. The four interfaces are discussed below.

3.2 The BMfSI interfaces

3.2.1 The sustainability innovation interface

The first interface refers to the relationships between sustainability innovations and business models (A in Figure 5). Table 2 presents the major issues and findings related to this interface.

The sustainability innovation interface	
Focus	Relationships between sustainability innovations and business models
Major issues	• Identification and understanding of barriers to commercialising and profiting from sustainability innovations • Role of the business model in overcoming commercialisation barriers to support market-based solutions to social and ecological problems
Major findings	• The business model's mediating function is based on the constructability and adaptability of business model elements, which can compensate for innovations' competitive disadvantages (e.g. high costs, marginal market segments) • Example: BP Solar's continuous business model innovation
Major references	• Boons & Lüdeke-Freund 2013 • Lüdeke-Freund 2013

Table 2: The sustainability innovation interface

Building on the emerging discourse on sustainability innovations and business models, Boons and Lüdeke-Freund (2013) provided the first systematic literature review in this new scholarly field. According to their review, the relationships between sustainability innovations and business models depend mainly on the focal point of sustainable entrepreneurs' innovation activities, which can be clean technologies, organisational forms, or ways to address social issues (Table 3). Depending on their main goals, for example the reduction of ecological burdens, the challenges of commercialising and profiting from sustainability innovations and the role of the business model differ. With regard to clean technologies, for example, an important finding is that sustainability scholars confirm the importance of the mediating function for commercial success. Three relevant technology and business model combinations can be distinguished: (i) new business models can employ given technologies; (ii) given business models can take up new technologies; and (iii) new business models can be triggered by new technologies (and vice versa).

Innovation focus	Supportive and mediating business model functions
Technological innovation	"... sustainable business models with a focus on technological innovation are market devices that overcome internal and external barriers of marketing clean technologies; of significance is the business model's ability to create a fit between technology characteristics and (new) commercialization approaches that both can succeed on given and new markets." (ibid., p. 14)
Organisational innovation	"Business model change on the organizational level is about the implementation of alternative paradigms other than the neoclassical economic worldview that shape the culture, structure and routines of organizations and thus change the way of doing business towards sustainable development; a sustainable business model is the aggregate of these diverse organizational aspects." (ibid., p. 15)
Social innovation	"... sustainable business models enable social entrepreneurs to create social value and maximize social profit; of significance is the business models' ability to act as market device that helps in creating and further developing markets for innovations with a social purpose." (ibid., p. 16)

Table 3: Major foci of sustainability innovation and business models
(source: Boons & Lüdeke-Freund 2013)

Going beyond the question of how to combine innovations and business models for commercial purposes, Wells (2008) sees an important normative dimension in this context and argues that "the business model undoubtedly influences how consumers think about the product, and the normative rules that shape expectations" (ibid., p. 84). As an example, if electric power is offered as a low-cost commodity, users will treat it accordingly, whereas this is only feasible because of high externalised costs, e.g. for nuclear waste treatment or solar power subsidies (Lüdeke-Freund & Opel 2013). That is, not only the innovation in question determines if and how it will unfold sustainability effects. The way it is brought to customers can be equally important – rebound effects due to an increasing demand for more efficient products are a common example of unintended problems caused by supposedly green innovations. The questions sustainable energy entrepreneurs have to answer in this context are: which societal problems shall be solved, e.g. supplying cost competitive green power with minimal negative externalities, and what are the major barriers to commercialising according energy solutions (cf. Wüstenhagen & Boehnke 2008)?

An in-depth case study on BP Solar, the former solar photovoltaics (PV) subsidiary of British Petroleum, dealt with these questions (Lüdeke-Freund 2013). Using the framework proposed by Schaltegger et al. (2012) (Section 3.2.2), the study re-constructed BP Solar's strategy and business model innovations to show how the company commercialised its solar technologies. With regard to the Teecian challenges (Section 2.2.1), the company was seeking an optimal appropriability regime (through highly specialised, proprietary cell and module manufacturing), pursued the development of a dominant design (by upscaling crystalline solar cell mass production), and avoided the dependency on external complementary assets (by integrating all value chain steps). Therefore, BP's solar business model was originally based on full integration as well as buying-in and developing proprietary processes and product designs. With this business model, BP Solar became a major PV company with a world market share at one time of 20%, and the company contributed significantly to the PV industry's growth.

To overcome specific challenges of sustainable energy innovations (Section 2.2.2; cf. Wüstenhagen & Boehnke 2008) BP Solar pursued a versatile strategy to align its business model to the characteristics of its PV technologies and solar power in general. The problem of radicalness was solved with a special buy-in strategy: BP Solar did not develop breakthrough innovations itself, such as new silicon casting processes or radically different solar cell layouts, but bought smaller companies and their innovations (e.g. Lucas and Solarex), which were then commercialised through BP Solar's fully integrated value chain (*business infrastructure design*). The problem of system-level change was solved, inter alia, with special downstream services including total system design as well as installation and financing services to support customers' decisions for self-produced green power (*value proposition* and *customer interface design*). By focusing on countries and states with munificent public solar policies, e.g. California with its solar deployment programs or Germany with its feed-in tariffs (Hansen et al. 2013), the company tried to optimise its revenues while at the same time production costs were reduced through outsourcing (*business infrastructure* and *financial model design*).

In sum, the sustainability innovation interface helps to focus on crucial relationships between distinct innovations and business models. Boons and Lüdeke-Freund (2013) found that scholars agree on the business model's mediating function which is important to systematically deal with barriers to commercialisation. The case of BP Solar illustrates the alignment of business model elements with the characteristics of a certain clean energy technology and how this can lead to commercial success (Lüdeke-Freund 2013). However, BP Solar also illustrates that maintaining a business case for sustainability innovation is a real challenge (the company was shut down in 2011).

3.2.2 The business case for sustainability interface

The second interface deals with business case effects resulting from sustainability innovations and corresponding business model alignments (B in Figure 5).

The business case for sustainability interface	
Focus	Relationships between business models for sustainability innovations and business cases for sustainability
Major issues	• Business case effects based on business models and their alignment/innovation • Effects on strategic business case/success drivers • The interplay of sustainability strategies and business model alignments as a strategically managed "business case platform"
Major findings	• The business model's mediating function is supported by the possibility to apply different degrees of business model alignment and innovation, which resonates with a company's sustainability strategy • Example: BP's solar business case based on strategically managed business model innovations and success drivers
Major references	• Schaltegger et al. 2012 • Lüdeke-Freund 2013

Table 4: The business case for sustainability interface

The focus of this interface is on the development of strategic success drivers like costs, risks, or reputation. In line with the framework of Schaltegger et al. (2012), this interface is less about aligning business models with particular innovations, but about understanding how the aligned models contribute to developing and improving business case drivers. Seen this way, innovations and business case effects are two sides of the same coin, intermediated by the business model. Table 4 summarises and Figure 6 illustrates this rationale. The latter also serves as a more nuanced description of the horizontal axis of the BMfSI framework.

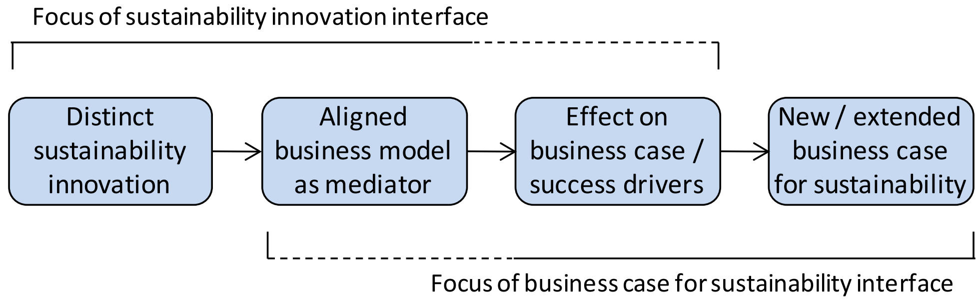

Figure 6: "Event chain" from sustainability innovation to business case for sustainability

Knowing that business cases do not automatically emerge from the "right" combination of innovations and business models, Schaltegger et al. (2012) followed the hypothesis that "mapping the links between business models and business cases for sustainability may be worthwhile to get *from single and event-driven business cases for sustainability to business models for sustainability,* which serve as templates for reproducing the respective business cases on a regular basis" (ibid., p. 102, italics added). The idea of a reproducible "template" may be provocative and sound like "ready-made business cases", but it is comparable to Elkington's (2004) analogy of the business model as the DNA of business (cf. Lüdeke-Freund 2009). In other words, if sustainable entrepreneurs learn to employ their business models like a manageable and malleable platform for their innovation activities, they will increase their business case opportunities in a more systematic way. The examples described by Boons and Lüdeke-Freund (2013) and the BP Solar case study, despite the company's closure, support this view (Lüdeke-Freund 2013).

Therefore, Schaltegger et al. (2012) developed systematic links between the four generic business model pillars (Section 2.3.1, Figure 3) and the most important drivers of business cases for sustainability (cf. Schaltegger & Lüdeke-Freund 2013). Table 5 shows exemplary interrelations between these drivers and a business model's value proposition (for interrelations with the business infrastructure, customer interface, and financial model see Schaltegger et al. 2012, p. 107).

Business case driver	Business model value proposition
Costs and cost reduction	Products and services with lower energy or maintenance costs for customers
Risk and risk reduction	Lowering societal risks through products and services can create value to certain customer segments
Sales and profit margin	Environmentally and socially superior products and services require modified or new value propositions to turn into sales and profits
Reputation and brand value	Sustainability as distinctive element of good corporate reputation and brand value
Attractiveness as employer	A companies' offerings and value propositions allowing for personal identification to attract employees
Innovative capabilities	Unfolding the full sustainability-potential of innovations enables modified or new value propositions

Table 5: Exemplary interrelations between value proposition and business case drivers (source: Schaltegger et al. 2012, p. 107)

Furthermore, Schaltegger et al. (2012) argue that the creation or modification of business models is directly related to the sustainability strategy of a company. That is, if the strategy is defensive, rather weak business model alignments should result, and, on the contrary, proactive strategies should lead to radical alterations (for the underlying strategy typology see Henriques & Sadorsky 1999). For example, a company with a defensive human resources strategy might attract personnel only with high salaries, whereas sustainability-oriented employees might prefer companies with an alternative organisational culture that pays attention to a variety of employees' needs as well as the natural environment (cf. Ehnert 2009). In this case, further reaching organisational sustainability innovations are required, which might lead to, or even depend on, business model alignments (cf. Table 3; see also Stubbs & Cocklin 2008).

The case of BP Solar is a rich illustration of how sustainability strategies, success drivers, and business cases interrelate as well as the role business model innovation can play in this context (Lüdeke-Freund 2013). The study does not only show how the company aligned its business model with its PV products and services (Section 3.2.1), the according effects on BP's "solar business case" were also re-constructed. Expectedly, the costs of solar power were the most important driver of, and barrier to, achieving a solar business case. Therefore, many of the company's business model innovations were dedicated to achieving cost reductions, resulting in a traceable "optimisation path" that included, inter alia, production outsourcing and licensing and led to the deconstruction of the originally integrated value chain. After BP Solar had implemented its dominant designs, the benefits of foreign low-cost manufacturing (a complementary asset) appeared to outweigh the benefits of a tight appropriability regime completely controlled by BP Solar itself. Therefore, the case is also a textbook example of how clean technology firms deal with the Teecian challenges of profiting from innovation (Section 2.2.1).

However, due to these and further sustainability-related innovation challenges particular attention must be paid to public policies and the availability of financial capital (Section 3.1).

3.2.3 The public policy interface

Public policy makers try to tackle the great sustainability problems like climate change, resource depletion, poverty, and social injustice not only by regulation, but also by motivating entrepreneurial and market-based solutions. Like other types of innovation, such solutions need public policy support to reduce the inherent risks of R&D activities and market entry and allow for a transition towards more sustainable social, economic, and technological systems (Elzen et al. 2004; Grubb 2004; Rotmans et al. 2001). Therefore, the third BMfSI interface deals with the relationships between public policies and business models for sustainability innovations (C in Figure 5; Table 6).

The public policy interface	
Focus	Relationships between public policies and business models for sustainability innovations
Major issues	• Identification and understanding of "built-in" competitive disadvantages of sustainability innovations and the need for public policy support to adjust for these disadvantages • Role of public policies in providing complementary assets needed by new and potentially sustainable business models to commercialise solutions to social and ecological problems
Major findings	• The business model's mediating function allows entrepreneurs to adapt flexibly to different policy environments (e.g. different types of clean technology support) • Solar policies in major markets (China, Germany, USA) systematically provide complementary assets like grid access, financing, and specially trained workforce • Example: country-specific adaptation of BP's solar business models
Major references	• Hansen et al. 2013 • Lüdeke-Freund 2013

Table 6: The public policy interface

As argued in Section 2.2.2, clean technologies and offerings for underserved social groups face, inter alia, the double externality problem when it comes to their commercialisation (Cohen & Winn 2007; Hockerts & Wüstenhagen 2010; Rennings 2000). No matter how well aligned business models are with the underlying socially and/or ecologically-oriented innovations, they often struggle with competitive disadvantages in terms of higher costs, system incompatibilities, or cultural barriers. Better Place's insolvency is a good example for how fragile pioneering business models can be, despite raising nearly one billion dollars from banks and investors (Reed 2013). Therefore, public policies are needed that burden unsustainable processes, products, and services, such as fossil-fuelled combustion engines, *and* support socially and ecologically superior alternatives (Beltramello et al. 2013; Bisgaard et al. 2012; Hockerts & Wüstenhagen 2010). Using Teecian language, the introduction and maturing of business models for sustainability innovations need public policies that make available complementary assets (given that demand side potential and no insurmountable cultural barriers exist) and provide for a stable institutional environment.

These disadvantages can be seen as "built-in" flaws in sustainable entrepreneurs' business models. For example, if a solar entrepreneur commercialises a new technology without public subsidies, the underlying business model will always have a relatively weaker financial model, due to less externalised costs as compared to conventional technologies (Lüdeke-

Freund & Opel 2013). This is a massive barrier to the creation of private benefits for entrepreneurs and technology users (cf. Wüstenhagen & Boehnke 2008). Public policy makers need to understand these disadvantages to design effective support instruments (cf. Beltramello et al. 2013; Bisgaard et al. 2012). In this context, Johnson and Suskewicz (2009) point out that government support should not only focus on single technologies but also on the system to which these belong, as well as on nascent business models that try to establish these technologies or even transform the respective system. With regard to public policy design, Hansen et al. (2013) used the technology policy theory of Mowery et al. (2010) to develop a set of 18 design principles for effective renewable energy policies that were applied to the case of solar power.

Hansen et al. (2013) found, inter alia, that the policies most commonly used to support solar power are demand pull policies, i.e. approaches to spur the diffusion and employment of PV technology, for example performance regulations, financial incentives, or government procurement. Technology push policies, i.e. approaches to stimulate basic research, corporate R&D, and manufacturing, were applied, too, but increasingly in conjunction with demand-oriented pull policies like installation support (US American approach) or feed-in tariffs (German approach). The authors analysed the public solar policies of China, Germany, and the USA and found that recent policies do indeed provide for strategic complementary assets like grid access (a direct connection to the existing meta-system), financial resources (crucial to new and unconventional business models with weak cash flows), or specially trained workforce such as solar system installers. As long as negative externalities are insufficiently regulated (Hansen and colleagues found according evidence in their study), these publicly supported assets remain vital for the survival of any solar business model (cf. Lüdeke-Freund & Opel 2013).

Though not directly studied, public policy effects can also be found in the BP Solar case study (Lüdeke-Freund 2013). Besides the manufacturing-oriented "optimisation path", BP Solar implemented a range of customer-oriented business model innovations ("new markets path"). In the USA, the company mainly sold small and medium-scale PV systems for private power production and direct consumption, while German customers mostly use their systems to sell the electricity to the grid based on grid access regulation and feed-in tariffs (which will change in the future due to new regulations in favour of direct marketing and direct consumption). Traditionally, US solar policies rather support purchase and installation of PV systems, whereas German policies support their employment through guaranteed revenues from power production (Hansen et al. 2013). In consequence, BP Solar's business models for the USA and Germany differed, inter alia, in terms of additional services: BP Solar offered special financing models in the USA, e.g. power purchase agreements, which was not necessary in Germany (but will be in the future).

In sum, public policies not only provide a level playing field for sustainability innovations, they also shape sustainable entrepreneurs' business models.

3.2.4 The financing interface

One of the major reasons for public policy support is the limited availability of financial capital for social and eco-innovations (e.g. Grubb 2004; Murphy & Edwards 2003; Yunus et al. 2010). In the OECD study on green business models, Beltramello and colleagues conclude accordingly: "Access to financing is a major constraint for many new business models ... financing is an important challenge for many young and innovative firms, and also for larger and riskier business models that engage in more systemic or radical innovations." (Beltramello et al. 2013, p. 9) The fourth and last BMfSI interface deals with selected financing issues (D in Figure 5; Table 7).

The financing interface	
Focus	Relationships between financing and business models for sustainability innovations
Major issues	• Identification and understanding of financing challenges related to sustainability innovations • Role of the financial model as an integral part of the business model
Major findings	• The business model's mediating function allows sustainable entrepreneurs to align their financing models, at least to some degree, to customers and investors' needs and particular types of innovations (e.g. clean energy technologies) • Financiers and investors' decisions might be biased by non-financial information, which opens up new possibilities for financing strategies, for example based on brand and bankability effects • BP Solar made financial model innovation an integral part of its business model innovation strategy to support its mass market businesses
Major references	• Hansen et al. 2013 • Lüdeke-Freund 2013 • Lüdeke-Freund & Loock 2011a

Table 7: The financing interface

From a Teecian perspective, financial capital can be seen as a complementary resource if it has to be acquired from third parties (Teece 2006, 2010). Capital needs, risks, and financiers differ along the innovation cycle from basic research to market diffusion. The most critical phase of this cycle is the passage from R&D and demonstration to commercialisation: the so-called "valley of death", which is an empirically proven financing gap between initial public funding and regular private financing (Grubb 2004; Hampl 2012; Murphy & Edwards 2003; Wüstenhagen & Menichetti 2012). Once the valley has been survived, sustainable entrepreneurs and their innovations have to make their way from niche to mass market (Hockerts & Wüstenhagen 2010; Schaltegger & Wagner 2011) – another critical phase in which business models can make the difference between "life and death".

In this context, different financing issues related to the market diffusion of solar power were studied (Hampl et al. 2011; Hampl & Lüdeke-Freund 2013; Lüdeke-Freund & Loock 2011a, 2011b; Lüdeke-Freund et al. 2012a). The focus was on the question whether the financing success of PV projects, i.e. medium and large-scale solar power installations realised on project basis (Lüdeke-Freund & Loock 2011a, 2011b), depends on specific project and business model characteristics. The starting point was a conjoint experiment with 43 PV financing experts from German banks to measure the importance of different attributes such as debt service cover ratio, project size, equity ratio or the employment of low-cost and premium brand solar modules and inverters (ibid.). This experiment revealed a "brand bias": the employment of premium brand technologies was rated as most important criterion, i.e. even more important than quantitative financial indicators. From a behavioural finance perspective, this bias can be interpreted as so-called overconfident decision making based on heuristics, i.e. rules (of thumb) used to simplify complex decision situations (Lüdeke-Freund & Loock 2011b). It can be concluded that PV projects with premium brand technologies should have better access to financial capital, which is an important finding for the development of roll-out strategies in which the "bankability" of technologies plays an important role (Hampl et al. 2011; Lüdeke-Freund et al. 2012a). PV project developers can use these insights to optimise their business models. Instead of striving for lowest costs, investing in premium brand technologies can pay-off in terms of improved bankability and access to debt capital (an ongoing study finds similar effects with equity investors; Hampl & Lüdeke-Freund 2013).

That is, premium brand modules and inverters can support the financial model, value proposition, and marketing approach of PV project developers' business models (Loock 2010; Lüdeke-Freund & Loock 2011a). Their cautious design can be used to balance trade-offs between the costs for premium brand components on the one hand and debt and equity investors' preferences on the other. New business model design principles like a preference-based segmentation of investors might offer new pathways to overcome finance-related barriers to the diffusion of clean technology innovations.

However, it has to be considered that these brand and bankability effects might be successively outweighed by major trends of the maturing solar industry: changing policy regimes and their regional specifics (Hansen et al. 2013), the increasing commoditisation of PV technologies (Hampl et al. 2011; Lüdeke-Freund et al. 2012a), and the pressure to keep up profit margins for large-scale investors require continuous business model innovation and learning. For example, BP Solar was following two innovation paths to keep up with the industry's development (Lüdeke-Freund 2013): the "optimisation path" led to an outsourced low-cost production model and the "new markets path" introduced various new financing models for BP's private, commercial, and utility-scale customers. In the last phase of its business model evolution, BP Solar developed many features of a financial service provider.

In sum, financing issues are inherent in the business model due to the integration of financial model elements (Section 2.3.1). Therefore, creating and managing business models and business cases for sustainability innovations is always related to creating and managing (new) financial models to survive the "valley of death" and allow sustainable entrepreneurs to reach out to the mass market.

4 Summary

This paper introduces the *business models for sustainability innovation* (BMfSI) framework to support and systematically structure research on sustainable entrepreneurship with an innovation and business model focus. Therefore, the framework links a common business model concept to theories of sustainable entrepreneurship with an emphasis on sustainability innovation and the business case for sustainability concept. Moreover, the business model's social and artificial nature is discussed to expose it as a socio-artificial construct. Understanding this construct characteristic is a precondition for effectively using the business model as a device that fulfils different functions in reality – such as allowing sustainable entrepreneurs to create and manage business cases for their innovations.

Furthermore, this paper argues that the most important business model function for the creation of social, ecological, and economic value is the mediating function that can help to overcome the most important barriers to profiting from sustainability innovation. This function is deduced mainly from Chesbrough and Rosenbloom's (2002) theory about the business model as a focusing device that can unlock the latent economic value of technology innovations. This idea is transferred to the BMfSI framework to bring forward the argument that business models can also be used to unlock innovations' latent sustainability potential.

Based on these theoretical foundations, four major BMfSI interfaces are defined and used to summarise and discuss the major results from the underlying doctoral research project. In the following, these results are finally used to answer the research questions formulated in the introduction to this paper.

1) *What are the major barriers to commercialising sustainability innovations?*

General and sustainability-specific barriers can be distinguished. Teece clearly defines these general barriers in his "profiting from innovation" framework (Teece 1986, 2006). These Teecian challenges relate to the appropriability regime, dominant design, and complementary assets of innovations and mainly emphasise the strategic positioning of an innovator towards his competitors, customers, and further value network actors. While Teece mainly refers to technological innovation without considering social or ecological issues, the literature on sustainability innovation discusses further barriers. To start with, discursive ambiguity and methodological constraints are barriers that result from the impossibility to agree on a common understanding of sustainable development and sustainability, respectively, and measure the degree of their achievement. Related to this are directional risks, which imply that the social, ecological, and economic effects of innovations cannot be fully anticipated. Furthermore, many authors call for radical and system-level innovations to replace unsustainable dominant designs and social and technological regimes. Finally, the double externality problem, which refers to sustainable entrepreneurs' double burden from innovation spillovers and internalised external effects, is the most fundamental barrier to profiting from sustainability innovation.

2) *What is a business model, and how does it facilitate business cases for sustainability innovations?*

The literature review shows that the business model is mostly defined as a concept or framework with different model characteristics and functions that allow researchers and practitioners to define and deal with selected aspects of business reality. To capture the targeted aspects, for example a company's offerings, business infrastructure, or value creation logic, the constituting business model elements and their relationships have to be defined. That is, a representing construct has to be developed, which can assume the form of verbal definitions, diagrams, concepts, or more complex reference systems. Building on a constructivist perspective, the business model can be defined as a socio-artificial construct that fulfils its different functions through the facilitation of social interaction and through the possibility to employ it according to the ideas and needs of the involved social actors. This framework paper uses the business model concept of Osterwalder and Pigneur (2010) due to its well documented acceptance among researchers and practitioners.

The business model's often assumed potential to support sustainable entrepreneurs in creating and managing business cases for their innovations is based on its mediating function, i.e. the iterative and context-specific alignment of business model elements with the characteristics of socially and ecologically-oriented innovations. The four BMfSI interfaces, which relate to sustainability innovation, business case, public policy, and financing issues, systematically structure different aspects and contexts of this mediating function. In other words, the framework suggests that business models can support sustainable entrepreneurs and their business cases through the continuous alignment of their business model elements on the company-level, taking into account their various interrelations with the wider business environment. This perspective goes beyond the mainstream business model management and innovation discourses because further challenges are recognised as being rooted in the deliberate internalisation and reduction of negative social and ecological effects. The internalisation and reduction of such effects confronts sustainable entrepreneurs with the above summarised barriers to profiting from sustainability innovation.

At this stage, the BMfSI framework cannot provide final answers to the more practical "how to" questions that directly emerge out of this study, as for example: "How to successfully commercialise an e-mobility system or a large-scale solar power project in the Sahara Desert?" However, the framework can support researchers and practitioners in asking the "right" business model-centred questions and developing appropriate research strategies to find answers. This approach is illustrated by referring to the results from different empirical studies on the solar photovoltaic industry.

3) How to develop a general "business models for sustainability" concept?

Although this paper develops the BMfSI framework on a theoretical and hence general level, further basic issues at the intersections of business models and corporate sustainability need attention. Researchers and practitioners alike (see e.g. the Forum for the Future's "Sustainable Business Model Group") increasingly ask the following questions: "What is a sustainable business model?", or "What is a business model for sustainability?" These questions can and shall not be answered here. Firstly, the barriers to sustainability innovations identified above, especially those problems related to discursive ambiguity and methodological constraints, inhibit the formulation of (seemingly) final answers. Secondly, despite the necessary generalisations of business and management research, every organisation is unique in itself and within its specific context. Research on business models for sustainability might be a valuable guide and provide assistance in discovering new approaches, such as the currently emerging "hybrid business model" stream, but finally, it is up to individual decision makers to develop their specific ways of becoming sustainable entrepreneurs and contributing to corporate sustainability.

However, different forms of guidance towards business models for sustainability were developed in two publications that resulted from the underlying doctoral research. The first guidance is a theoretical bridge between business cases for sustainability and business models:

> "Based on the understanding of a business *case* for sustainability, a business *model* for sustainability can be defined as supporting voluntary, or mainly voluntary, activities which solve or moderate social and/or environmental problems. By doing so, it creates positive business effects which can be measured or at least argued for. A business model for sustainability is actively managed in order to create customer and social value by integrating social, environmental, and business activities." (Schaltegger et al. 2012, p. 112, original italics)

The second guidance is a set of normative principles that can help in identifying and developing such business models:

> "1. The *value proposition* provides measurable ecological and/or social value in concert with economic value. The value proposition reflects a business-society dialog concerning the balance of economic, ecological and social needs as such values are temporally and spatially determined. For existing products, a particular balance is embedded in existing practices of actors in the production and consumption system; for new products or services, such a balance is actively being struck among participants in the evolving alternative network of producers, consumers, and other associated actors.
>
> 2. The *supply chain* involves suppliers who take responsibility towards their own as well as the focal company's stakeholders. The focal company does not shift its own socio-ecological burdens to its suppliers. This condition requires that a firm actively engages suppliers into sustainable supply chain management, which includes, for example, forms of social issue management and materials cycles that avoid/reuse wastes.
>
> 3. The *customer interface* motivates customers to take responsibility for their consumption as well as for the focal company's stakeholders. The focal company does not shift its own socio-

ecological burdens to its customers. Customer relationships are set up with recognition of the respective sustainability challenges of differently developed markets as well as company-specific challenges resulting from its individual supply chain configuration.

4. The *financial model* reflects an appropriate distribution of economic costs and benefits among actors involved in the business model and accounts for the company's ecological and social impacts." (Boons & Lüdeke-Freund 2013, p. 13, original italics)

This guidance helps to define starting points for future research dedicated to the development of theories, concepts, and also more practically-oriented knowledge about business models for sustainability.

5 Future research

Finally, three major limitations shall be mentioned that point to opportunities for future research. First, the BMfSI framework is a theoretical firm-level framework and does not provide some kind of a "how to" guide for business model management in practice. Second, the research problems underlying the four BMfSI interfaces were treated in separate studies, which necessitated their subsequent integration. That is, the applied research questions and methodologies could not be synchronised in a way that would have been desirable. Third, regarding the challenges of sustainability innovation, it was found that the double externality problem is the most important barrier. This paper mainly discusses the role of public policies and the alignment of business models with these to overcome the double externality problem, but future research, for example on business models for clean technologies, should also focus on models that allow commercialising sustainability innovations without public policy support.

Future research should also explore possibilities to develop more practically-oriented concepts for sustainable entrepreneurs and corporate managers based on the BMfSI framework and its interfaces. The above proposed guidance can serve as a starting point for further conceptual and empirical research that provides a better fundament for a practitioner-oriented "translation" of the increasingly emerging research on business models for sustainability. Such transfer-oriented approaches should in any case include the development of performance measurement systems and instruments that help in qualifying and quantifying companies' sustainability performance on the business model level.

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B. Conceptual foundations ...

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Business models for sustainable innovation: state-of-the-art and steps towards a research agenda

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ABSTRACT

The aim of this paper is to advance research on sustainable innovation by adopting a business model perspective. Through a confrontation of the literature on both topics we find that research on sustainable innovation has tended to neglect the way in which firms need to combine a value proposition, the organization of the upstream and downstream value chain and a financial model in order to bring sustainable innovations to the market. Therefore, we review the current literature on business models in the contexts of technological, organizational and social innovation. As the current literature does not offer a general conceptual definition of sustainable business models, we propose examples of normative requirements that business models should meet in order to support sustainable innovations. Finally, we sketch the outline of a research agenda by formulating a number of guiding questions.

1. Introduction

In the past decade, research on sustainable innovations has expanded rapidly to increase our understanding of the ways in which new technologies and social practices enable societies to become more sustainable. Earlier special issues of this journal have focused on eco-innovation (Hall and Clark, 2003) and the diffusion of clean technologies (Montalvo, 2008). Also, in the past decade coherent perspectives have been introduced that look more systemically at the ways in which more sustainable technologies are adopted in society, such as transition management and innovation systems research (see Coenen and Diaz-Lopez, 2010 for a comparative overview). This research has contributed to our knowledge of factors that induce sustainable innovations, such as regulation and firm characteristics, and also show the interplay of factors in innovation and societal systems that determine the often complex journey of new ideas into products and services (Geels et al., 2008).

While an innovation is often distinguished from an invention by the additional condition of successful market introduction, the actual way through which firms succeed in bringing an invention to the market is relatively unexplored (e.g., Teece, 2006; Chesbrough, 2007a). While this issue is gaining increasing attention in the "mainstream" literature (Baden-Fuller et al., 2010), it is still underexplored in the field of sustainable innovation (Charter et al., 2008; Schaltegger et al., 2012; Tukker and Tischner, 2006; Wells, 2008).

In this article we focus on this gap. We look not so much at products or services themselves, nor at their physical attributes and sustainability impacts. Instead we focus on how business models and sustainable innovations interrelate and what can be learned from the current scientific literature. We search for links between sustainable innovations and the business model concept. The latter concept, which is drawn from the field of business management, captures key dimensions of successful market introduction: it specifies how a firm is able to earn money from providing products and services. This includes not only the value proposition to customers, but also the value creating constellation in which the firm connects to suppliers and acquires resources in a profitable manner. We propose that these elements are crucial for making sustainable innovations successful.

The questions we seek to answer in this article are:

What does the current scientific literature reveal about the interrelations between business models and sustainable innovations?

How can the business model perspective help to define future topics for research on sustainable innovation?

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By answering these questions, we contribute to the literature in three ways. First, we provide insight into the ways in which the sustainable innovation literature currently lacks attention towards aspects that are crucial for successfully marketing innovations. These elements are provided by incorporating the business model literature. Secondly, we propose a set of normative requirements under which business models for sustainable innovation should operate. Thirdly, we present a research agenda for sustainable innovation that incorporates the elements of business models.

While we focus on forging a link between sustainable innovation and business models in research, this link is also relevant for practitioners. As will become clear, the business model perspective reveals a number of components that need to be actively managed in order to "create customer and social value by integrating social, environmental, and business activities" (Schaltegger et al., 2012, p. 112).

We proceed by introducing the business model as a market device that is closely related to innovation (Section 2). Section 3 summarizes the literature on sustainable innovation and identifies three relevant levels of analysis: the organizational, inter-organizational and societal level. In combination with insights from early considerations of sustainable business models these lead us to propose basic normative requirements for business models that facilitate sustainable innovations (4.1). These basic requirements are then further developed, based on literature revealing general barriers to marketing sustainable innovations (4.2) and current literature dealing with business models for technological, organizational and social innovations (4.3). Section 5 reflects the main findings from our review and Section 6 concludes with five key questions for setting up an agenda for research on sustainable innovation that integrates the business model perspective.

2. The business model: an emerging concept

Identifying business models as a means of creating value through sustainable innovations requires a clear understanding of the unit of analysis.[1] In order to build on the diversity which is present in the literature on this topic, we screened 87 journal articles on business models which could be identified in the Thomson Reuters database Web of Science. Our search string was "business model" in article titles, to make sure that business models were explicit objects of research. We searched for articles from 1990 to 2010, whereas the earliest ones were actually published in 2000. Further articles were identified through cross-reference searches which were essential to identify articles on sustainable business models. In sum we worked on a set of 115 articles, a handful of books and some research working papers.

Combining Osterwalder (2004) and Doganova and Eyquem-Renault (2009) we distinguish the following elements of a generic business model concept:

1. *Value proposition*: what value is embedded in the product/service offered by the firm;
2. *Supply chain*: how are upstream relationships with suppliers structured and managed;
3. *Customer interface*: how are downstream relationships with customers structured and managed;
4. *Financial model*: costs and benefits from 1), 2) and 3) and their distribution across business model stakeholders.

For existing firms it is possible to specify these elements. For new ventures this may be unclear. In this context, a business model is used as a plan which specifies how a new venture can become profitable. Doganova and Eyquem-Renault (2009) argue that a business model is a "market device" (Callon et al., 2007), an intermediary between different innovation actors such as companies, financiers, research institutions, etc., i.e., actors who shape innovation networks. In their theory, such networks are created through what they call "narratives" and "calculations" which entrepreneurs circulate to describe their ventures and to construct markets. Here, the business model is seen as a reference point for communication among the different actors with whom entrepreneurs engage. Markets for innovations thus emerge through interaction between these actors who also interfere with different kinds of devices (e.g., support materials such as analysts' reports, presentations, software, or money). The business model, as it connects actors through narratives and calculations (see also Magretta, 2002), can be interpreted as such a market device (Doganova and Eyquem-Renault, 2009). This perspective is relevant because marketing sustainable innovations may require a rethinking of the terms of competition and collaboration among the actors engaged in the corresponding innovation networks.

In his overview of business model literature, Wirtz (2011) identifies three streams. The first stream focuses on technology. Explicating business models became popular during the internet boom, when firms and analysts came to realize that existing ways of earning a profit were not suitable for capitalizing on new technologies: web-based products and services (e.g., Ghaziani and Ventresca, 2005; Timmers, 1998). Hence, there is a substantial body of literature which focuses on the consequences of particular technologies on how firms organize to earn profits. This is relevant for the field of sustainable innovation since technologies that contribute to sustainability may have a similar effect.

The second, organizational, stream emanates from this work and deals with the business model as a strategic management tool to improve a company's value chain (e.g., Linder and Cantrell, 2000; Tikkanen et al., 2005). Here, a business model serves as a development tool for business systems and architectures for representing, planning and structuring business with an emphasis on organizational efficiency.

A third stream is strategy-oriented. It adds the element of market competition to the efficiency focus of the second stream (e.g., Afuah, 2004; Casadesus-Masanell and Ricart, 2010; Chesbrough, 2007a; Hamel, 2000; Magretta, 2002). Common sense amongst strategy-oriented business model scholars is that creating and delivering customer value lies at the heart of any business model (e.g., Afuah, 2004; Chesbrough, 2010; Johnson, 2010; Osterwalder and Pigneur, 2009; Teece, 2010; Zott and Amit, 2010). Moreover, while creating and delivering customer value, the business model itself can become a source of competitive advantage – by means of business model innovation (e.g., Chesbrough, 2010; Johnson, 2010; Markides and Charitou, 2004; Mitchell and Coles, 2003). Companies striving for a competitive edge through unique value propositions can use the configuration of their business models' building blocks to execute their strategies on the market. Therefore, "a business model is the direct result of strategy but is not, itself, a strategy" (Casadesus-Masanell and Ricart, 2010, p. 212). In this sense, strategic interaction between rivals results in competition based on business model modifications (Casadesus-Masanell and Ricart, 2010). An important question for future research, which cannot be dealt with in this article due to page limits, is to what extent strategy as business model modification

[1] A systematic overview of perspectives is Wirtz's book on business model management (Wirtz, 2011). Moreover, Long Range Planning published a special issue on latest business model research (2010, Vol. 43, No. 2/3) and a Harvard Business Review paperback collection on business model innovation was released in 2010; a second HBR paperback on "Rebuilding Your Business Model" was published in 2011. For other definitions, see, for example, Johnson et al., 2008, Chesbrough, 2010, Wirtz, 2011, or Zott et al., 2011.

and competition can support the marketing of sustainable innovations.

Our review shows that innovation is a dominant topic in the literature on business models as an important aspect of creating competitive advantage and renewing organizations (about 50 articles deal with business model innovation and more than 20 with business models *and* innovation). Two roles of business models can be distinguished (Baden-Fuller et al., 2010; Wirtz, 2011). First, business models can support the strategic marketing of innovative processes, products and services (e.g., Pateli and Giaglis, 2005; Teece, 2010; Zott and Amit, 2008, 2007). Secondly, business models themselves can be changed and innovated to provide competitive advantage by changing the terms of competition (e.g., Chesbrough, 2010; Demil and Lecocq, 2010; Johnson, 2010; Zott and Amit, 2010). Situations where process or product innovations impact business model designs and vice versa are also explored, especially by Chesbrough (e.g., Calia et al., 2007; Chesbrough, 2007b; Chesbrough and Rosenbloom, 2002; Chesbrough et al., 2006).

In the management literature there is thus a clear linkage between the business model of a firm and its innovation activities. Following this lead, we propose that to advance research on sustainable innovation the linkage to business models should be further explored. This requires first of all that we make clear what makes innovations sustainable.

3. Sustainable innovation and sustainable business

This section starts with an overview of the literature on sustainable innovation (Section 3.1). We then summarize earlier discourses where business models were acknowledged as a crucial aspect of entrepreneurial and managerial sustainability activities (Section 3.2). We then present current work on sustainable business models with an innovation focus (Section 4).

3.1. Research on sustainable innovation

A systematic review of the literature on sustainable innovations and related concepts is beyond the scope of this article. Getting an overview is further complicated because the literature on sustainable innovation is hampered by a lack of conceptual consensus. A recent overview (Carrillo-Hermosilla et al., 2010) lists many different definitions of the term “eco-innovation”, a label which is often used interchangeably with sustainable innovation. Related terms such as clean(er) technologies are also used in a way that overlaps with innovations that have a superior ecological performance. This situation is a consequence of the fact that researchers from many different disciplines have picked up this topic: evolutionary economics, science and technology studies, innovation economics, economic sociology, and history. All of these focus mainly on innovations related to the ecological impact of a product or service. There is, however, a rapidly growing body of work focusing on the social aspect under the banner of so called “bottom of the pyramid” initiatives (e.g., Prahalad, 2005; Prahalad and Hart, 2002; Seelos and Mair, 2005, 2007; Yunus et al., 2010).

For our purposes, we rely on 5 recent publications that provide an overview of several segments of this literature (Weber and Hemmelskamp, 2005; OECD, 2009; Carrillo-Hermosilla et al., 2009; Arimura et al., 2007; Smith et al., 2010). We have structured research according to the level of analysis on which it focuses: the organizational, inter-organizational, and societal level. In our presentation we focus on ways in which researchers conceptualize the marketing of innovations.

At the *organizational level*, the focus is on the individual firm and its innovative capacities. Here, research focuses on the capacity to develop new technologies, and how to connect this within the firm to other functions (such as marketing and production) in order to come up with a marketable value proposition. While many contributions provide tools (such as for EcoDesign or calculating ecological impact), insight into the actual process of managerial decision making is limited (Visser et al., 2008 is an exception). More often, firms are treated as a black box, and researchers study the impact of various factors on its innovative capacities through statistical methods (Arimura et al., 2007; Horbach, 2008). The Porter hypothesis and the research it has stimulated is an example of such work, where the impact of regulation on the capacity of firms to develop environmental innovations is studied. Some of these studies measure innovative capacity in terms of input (R&D expenditure; Jaffe and Palmer, 1997) or patents (Brunnermeier and Cohen, 2003). If anything, this shows a neglect of the importance of the process of marketing innovations. This is shown by a similar approach to the adoption of cleaner technologies which also looks at individual factors affecting adoption behavior of firms (Montalvo, 2008).

Studies at the organizational level often do not explicitly address the mechanisms through which influencing factors affect innovative capacities or help to produce concrete results in terms of marketed innovations. At the *inter-organizational level* such mechanisms begin to come into focus. Examples are studies on the adoption and diffusion of clean technologies (Kemp and Volpi, 2008). Also, modeling studies give insight into the complex way in which, for instance, regulatory standards and supply chain pressures interact in a supply chain (Saint-Jean, 2008; Seuring and Müller, 2008). A substantial amount of work has been done under the banner of (environmental) innovation systems. These studies draw a system boundary around the network of actors who contribute to the innovation process (Edquist, 1997; Weber and Hemmelskamp, 2005). A specific strand of this literature seeks to identify functions that need to be performed by the system in order to produce successful new technologies (Hekkert et al., 2007). One of these functions is a typical business model function: the formation of markets (e.g., Amit and Zott, 2010; Seelos and Mair, 2007). Inter-organizational studies of sustainable innovation bring into focus the relevance of what we have distinguished above as the second and third elements of a business model: the relationships with other actors (i.e., suppliers and customers). At the same time, they often fail to link these elements to the analysis of value propositions and financial models. However, this systemic view on connecting actors in an innovation network is related to the market device functions proposed by Doganova and Eyquem-Renault (2009).

Studies at the *societal level* draw the system boundary even wider, aiming to understand what is called transitions (an overview is provided by Smith et al., 2010). While there is criticism to this perspective as a management approach to innovations at the societal level (Shove and Walker, 2007), there is a growing body of literature which seeks to understand societal shifts in terms of technological changes where the existing technology is conceptualized as a regime which is challenged by new innovations that occupy niches in the wider landscape (Geels, 2005). Given their scope, these studies also focus on the first element of business models, i.e., that of the definition of value which brings together actors around an existing or new technology. Unfortunately, most of the work done under this banner shows a lack of consideration for agency (Genus and Coles, 2008). As a result, it is difficult to link it to our perspective where the business model is put forward by a firm, and serves as a device which acts as a conduit to facilitate the problematic interactions among actors.

An earlier special issue of this journal (Hall and Clark, 2003) similarly focused on this crucial aspect: without a successful diffusion in society, eco-innovations are meaningless. In capitalist societies the market is a dominant coordination mechanism where such success is achieved. There it is defined as increased market share and profitable returns for the firms that bring a new product or service to the market. The premise of market success alone challenges any attempt of change. As will be discussed below, an additional challenge for the creation and further development of businesses towards sustainability is the co-creation of societal and economic profits. Looking at sustainable innovation from a business model perspective might shed light on how these challenges can be met.

3.2. Antecedents of a modern discourse on sustainable business models

In the literature on sustainable entrepreneurship and corporate sustainability management the concept of business models is still used in a fuzzy way (Lüdeke-Freund, 2009; Schaltegger et al., 2012). Nevertheless, general connections to corporate sustainability, including sustainable innovation, can be found, for example, in two classic articles.

Lovins et al. (1999) propose a four step agenda to align business practice with environmental needs. This agenda, labeled Natural Capitalism, consists of management principles beyond the often efficiency-centered perspective of environmental management – increase of natural resources' productivity; imitation of biological production models; change of business models; and reinvestment in natural capital. Important for our review is the fact that Lovins and colleagues see a change towards sustainable business models as crucial to realizing Natural Capitalism. But the emergence of such models requires a revision of distorted information and incentive systems: "the instruments companies use to set their targets, measure their performance, and hand out rewards are faulty" (Lovins et al., 1999, p. 12; see Burritt and Schaltegger, 2010 for more information on sustainability accounting and reporting). The necessarily distorted business models increase work force productivity, but at the same time they amplify exploitation of natural resources and sometimes even employees (Schnaiberg, 1980). Lovins and colleagues refer to the much-cited example of US-based carpet manufacturer Interface Inc. as a positive counter-example (Box 1).

> Box 1. Interface Inc. – a role model for ecologically enhanced business.
>
> *Interface Inc.* changed its business from manufacturing and selling carpets for office buildings to a billion-dollar floor-covering service-leasing model (Stubbs and Cocklin, 2008). The change to a service-centered business model lead to the new customer value proposition "floor-covering" and a more than thirty-fold reduced flow of materials (Lovins et al., 1999). The produce-and-use (up) logic changed to a model in which suppliers "get paid to provide the agreed-upon level of comfort, however that's delivered" (Lovins et al., 1999, p. 10). Such approaches can realign metrics, incentives, measurement and accounting practices with the goal of reducing ecological harm.

Lovins and colleagues' plea resonates with the work of Hart and Milstein (1999), who see sustainable development as a force of industrial renewal and progress – if managers learn to see the business opportunities connected to this challenge. They argue that three ideal types of economies can be differentiated: consumer, emerging, and survival economies. Each calls for different business strategies and models as their respective conditions for production and consumption differ considerably in the light of sustainable development. Thus, they conclude that "simply transplanting business models" (Hart and Milstein, 1999, p. 29) from one economy to another will run counter to sustainable development. Openness to social and technological leapfrog innovations is required to avoid replicating the weak points of dominant Western business models in emerging and survival economies (Hart, 1997). Consumer economies, highly industrialized nations with roughly one billion people, are characterized by great purchasing power, extensive infrastructures, and literally unlimited consumption possibilities. Here, business models have to change in a way that reduces corporate footprints and decouples production and consumption from social and ecological impacts. In survival economies, mainly based on rural lifestyles, lacking infrastructures of any kind and whose three to four billion people often suffer from unmet basic needs, companies have to come up with radical business model innovations that must inevitably deviate from common consumer models. Here, the authors refer to groundbreaking businesses like micro-credits (Grameen Bank) or low-priced ready-to-make kits for clothing (Ruf and Tuf jeans). The economies in between, two to three billion people in emerging countries, are characterized by satisfied basic needs and increasing purchasing power. According to Hart and Milstein, trends of rapid industrialization and urbanization urgently ask for new solutions to meeting familiar customer needs.

These two classic articles envision changing business models as a way to reduce negative social and ecological impacts or even as a way to purposefully achieve sustainable development. While Lovins and colleagues discuss business model change as a central step on their path towards Natural Capitalism, Hart and Milstein point to the fact that the world is a patchwork of different, in part even non-compatible, economies that require carefully selected business models – all the more, if economic development is to contribute to sustainable development. Having identified business model change as an important instrument to support sustainability-oriented businesses, we argue that this instrument is not an end in itself. Moreover, the business model concept has to be linked to approaches of sustainable innovation to identify possibilities of creating sustainable value.

4. Linking business models to sustainable innovation

In this section we aim to show how the business model perspective helps to better explore and understand how different types of sustainable innovations are marketed, and thus, how this perspective can become a new field of sustainable innovation research – a crucial topic that has only rarely been addressed (e.g., Charter et al., 2008; Wells, 2008). Building on the insights from Sections 2 and 3, we start with proposing a basic set of normative requirements that have to be met for business models to contribute to marketing sustainable innovation. We then confront these with literature on barriers that have to be overcome by *business models for sustainable innovation.*

4.1. Normative requirements for business models for sustainable innovation

The concept of sustainable innovation is grounded in wider normative concepts such as environmental sustainability or sustainable development (e.g., Boons, 2009; Carrillo-Hermosilla et al., 2009, 2010; Hall and Clark, 2003). Comparable conceptual notions of sustainable business models do not exist today (Lüdeke-

Freund, 2009; Schaltegger et al., 2012). This may be a result of the fact that sustainable development does not denote a specific content, but rather a process where ecological, economic and social values are balanced in continuous action (Lélé, 1991). From the literature on sustainable innovation we learn that this process involves inter-organizational networks and even wider societal systems. Such networks do not only include firms, but also other stakeholders. Based on these insights we use the four elements of a business model – value proposition, supply chain, customer interface, and financial model – identified earlier and propose a set of basic normative requirements that we believe need to be met for successfully marketing sustainable innovations:

1. The *value proposition* provides measurable ecological and/or social value in concert with economic value. The value proposition reflects a business-society dialog concerning the balance of economic, ecological and social needs as such values are temporally and spatially determined. For existing products, a particular balance is embedded in existing practices of actors in the production and consumption system; for new products or services, such a balance is actively being struck among participants in the evolving alternative network of producers, consumers, and other associated actors.
2. The *supply chain* involves suppliers who take responsibility towards their own as well as the focal company's stakeholders. The focal company does not shift its own socio-ecological burdens to its suppliers. This condition requires that a firm actively engages suppliers into sustainable supply chain management, which includes, for example, forms of social issue management and materials cycles that avoid/reuse wastes (Seuring and Müller, 2008).
3. The *customer interface* motivates customers to take responsibility for their consumption as well as for the focal company's stakeholders. The focal company does not shift its own socio-ecological burdens to its customers. Customer relationships are set up with recognition of the respective sustainability challenges of differently developed markets (Hart and Milstein, 1999) as well as company-specific challenges resulting from its individual supply chain configuration.
4. The *financial model* reflects an appropriate distribution of economic costs and benefits among actors involved in the business model and accounts for the company's ecological and social impacts (Maas and Boons, 2010).

These requirements are defined generically on purpose. For future research, more detailed and refined formulations may allow for empirical tests of their actual relevance. So far, they provide a basic set of normative principles for sustainable business models which need to be fulfilled in order to contribute to a successful marketing of sustainable innovations. These conditions do not specify a sustainable business model per se, nor do they explain how specific innovations are commercialized. Such questions can only be answered for specific firms operating in specified contexts.

But making these normative requirements explicit helps to understand that any innovation has to be successfully marketed to unfold its sustainability potential (Schaltegger and Wagner, 2008, 2011), and that the underlying business model has to operate according to certain principles to not contradict this potential. While an innovation *bears* an assumed sustainability potential, the underlying business model is the market device that allows (or hinders) to *unfold* this potential, given that certain barriers can be overcome: namely barriers of the institutionalized organizational memory and the external business environment (e.g., Carrillo-Hermosilla et al., 2009; Hall and Clark, 2003; Johnson, 2010).

4.2. Barriers to marketing sustainable innovations

Implementation and diffusion of innovations are often considered as challenges of introducing new technologies and designs, overcoming economic barriers and gaining acceptance among users, and sometimes even changing whole socio-technical systems (e.g., Charter et al., 2008; Geels, 2005). It is a special characteristic of sustainable innovations that they have to fit from a technical or organizational point of view, be economical *and* contribute to solving sustainability problems (e.g., Carrillo-Hermosilla et al., 2009; Charter et al., 2008; Hansen et al., 2009; Horbach, 2008). Our literature review shows that this challenge is increasingly discussed as a business model challenge (see Section 4.3).

Two generic situations can be imagined: The innovation, be it a process, product or service, fits with the existing business model (e.g., a company producing and selling light bulbs will be able to shift from conventional to energy saving bulbs); or it fits only to a certain degree or not at all (this will be the case when the light bulb producer delivers lighting services where the bulbs are only part of the value proposition). The latter situation calls for explicit awareness of the company's business model and the ability to identify and overcome internal as well as external barriers to bringing a new product or service to the market. Here, an important internal barrier is the *institutionalized organizational memory* consisting of business rules, behavioral norms and success metrics (Johnson, 2010; see also Lovins et al., 1999). These evolve and become firmly established once a business model is fully developed, and, as Johnson argues, "…these guidelines and control mechanisms are powerful inhibitors to the introduction of new business models" (Johnson, 2010, p. 46). Comparable obstacles can be identified in the *external business environment*. In many industries, such as automobile manufacturing or energy, characteristics like high capital intensity in concert with incumbents' resilience to disruptive technologies often lead to the dominance of locked-in "fire and forget" business models (e.g., Wells, 2008; Wüstenhagen and Boehnke, 2008). An example for an industry that is locked in its business environment is mobile telephony (Box 2).

Box 2. Mobile telephony – an unsustainable business model.

Mobile telephony provides an example of a locked-in business model with high ecological impact. A typical situation is that the marketing of mobile phones is a joint effort of the device producer and the network provider. Hardware is offered at substantially reduced prices, or even for free, combined with a long term contract with a network provider. While this is a viable model in terms of revenues for both the network provider and the hardware producer (Camponovo and Pigneur, 2003), it leads to a high level of substitution of technically functioning devices. Hardware firms offer new models at a high pace, fuelling new fashions among users. This business model leads to excessive resource use (especially rare earths) and negative social impacts (e.g., working conditions in coltan mines).

These barriers indicate that introducing a sustainable innovation requires a far-reaching approach to change things at the company level while taking into account external barriers imposed by the wider environment of the respective production and consumption system. This may be a risky and costly venture, for start-ups as well as for incumbents, which becomes even more complicated when complex social constructs like demands of sustainable development are to be integrated (Birkin et al., 2009a, 2009b; Boons, 2009; Charter et al., 2008). But at the same time, more systemic innovations are expected to have a greater sustainability potential (e.g., Hansen et al., 2009; Tukker and Tischner, 2006).

4.3. Business models for sustainable innovation – what the literature reveals so far

As a holistic and systemic concept (Baden-Fuller and Morgan, 2010), a business model perspective may be expected to contribute to a sustainable innovation agenda by opening up new approaches to overcoming internal and external barriers. In this subsection, we uncover this potential as described in the current literature.

Sixteen out of the identified 115 business model articles as well as five book chapters are directly concerned with business models and sustainability issues. Based on these sources, we defined three streams which appear to be most important with regard to sustainable business models: *technological, organizational, and social innovation*. It is important to recognize that these streams do not stand for separated phenomena. That is, for example, technological innovations might depend on organizational change (e.g., Interface Inc.; Box 1) or support social value propositions (e.g., "Grameen telephone ladies"; Box 4). However, for reasons of clarity we discuss the three streams separately.

4.3.1. Technological innovation

According to Wells (2008), the business model can be used as an analytical unit to explore and understand the economic logic of production and consumption systems revolving around the fulfillment of specific needs (e.g., mobility) through specific technological artifacts (e.g., automobiles) and which connect suppliers and customers through economic exchange relationships. He contrasts, for example, the economic logic of linear mass production businesses with specialized niche suppliers, and concludes that "the business model undoubtedly influences how consumers think about the product, and the normative rules that shape expectations" (Wells, 2008, p. 84). That is, the business model acts as a mediator between technologies of production and consumption – i.e., between how technological artifacts are made, the artifacts themselves, and how they are finally used – which also influences further stakeholders' perceptions of these technologies and the ways in which they are marketed (such as customers, regulators and competitors).

This role as market device can refer to three combinations of business model and technology[2] innovation (Table 1): a new business model can employ given technologies (1); existing business models can take up new technologies (2); and new business models can be triggered by new technologies, and vice versa (3).

These combinations pose different challenges. In case (1) existing products are offered in new ways; e.g., based on new modes of distribution and application (from selling carpets to floor-covering services) (e.g., Halme et al., 2007; Lovins et al., 1999) (Box 1). Here, the primary challenge is to convince customers of a new product or service handling. Case (2) refers to the integration of new production processes, products or services with a company's existing business model. The automobile industry illustrates the challenge of introducing new technological paradigms against an industry's dominant business model (e.g., Johnson and Suskewicz, 2009; Wells, 2008). In contrast, a textbook example of marketing a technological system innovation through new business models, case (3), is the electric mobility concept of Better Place as described by Johnson and Suskewicz (Box 3).[3]

Table 1
Business model/technology innovation combinations.

		Business model	
		Existing	New
Technology	Existing	Not considered here	(1)
	New	(2)	(3)

Box 3. Better Place – radical system innovation.

Better Place is the most prominent example of a system innovation and a radically different business model for a locked-in industry. The most important barrier is the infrastructure that is completely adapted to gasoline fueled cars (Wells, 2008). Users expect convenient, flexible and relatively low cost mobility – features that current battery-driven cars cannot offer. "But instead of focusing on how to make batteries work in the existing system, Agassi [founder of Better Place] asked what new system would be needed to make them as convenient, effective, and affordable as gasoline". (Johnson and Suskewicz, 2009, p. 56) Better Place separates car ownership (user) from battery ownership (Better Place) to make the battery a changeable item. That is, the user does not buy the expensive battery, but pays per kilometer. A close-meshed network of automatic change stations and a tracking system that directs the driver to the next station secure convenience and easy handling. As the costs per kilometer, including battery, network service and electricity, are lower than for gasoline, Better Place can use this margin to subsidize electric vehicles.

As the example in the Textbox shows, new technologies alone are insufficient to change paradigms of production and consumption systems. In combination with new business models this becomes possible.

Thus, sustainable business models with a focus on technological innovation are market devices that overcome internal and external barriers of marketing clean technologies; of significance is the business model's ability to create a fit between technology characteristics and (new) commercialization approaches that both can succeed on given and new markets.

4.3.2. Organizational innovation

In their studies on North European and Chinese companies Birkin and colleagues identify societal and cultural demands of sustainable development that evolve outside the economic sphere as drivers for organizational change in business enterprises (Birkin et al., 2009a, 2009b). Their understanding of a business model refers to a more general interpretation of doing business,

[2] As simplification, technology shall comprise production technologies as well as the resulting product/service offerings and their applications.

[3] We recognize the fact that the Better Place case is also about organizational innovation, but focus on the technology and system aspect for reasons of analytical clarity.

comparable to notions of the "US Model" or the "Asian Model" (e.g., Cappelli, 2009; Singh and Zammit, 2006). Birkin and colleagues argue that, as social and natural needs become institutionalized as concrete societal and cultural demands, these models will change radically. Hence, companies are expected to induce significant organizational adaptations in order to secure legitimacy and legality – and not least, business success. But the approaches observed in their studies are of rather incremental nature and primarily aim to integrate aspects of economic sustainability into existing business models due to constraints such as a lack of time, problems with the market model, cost aspects and vested interests. In sum, their descriptions fall short of highlighting companies which may serve as role models for their industries.

Stubbs and Cocklin (2008) follow a different approach and analyze the US-based carpet manufacturer Interface Inc. and the Australian Bendigo Bank in more detail to develop their "sustainability business model". Their perspective on organizational development is comparable to Birkin and colleagues since their conception starts from the assumption that sustainable business models are developed around sustainability concepts from the non-economic sphere that are transferred to the organizational level. A heuristic is derived from the two cases to describe how their characteristics contribute to corporate sustainability. This heuristic is a white list of preconditions, drivers and measures arranged in two dimensions (Fig. 1): *structural* and *cultural attributes* in the first dimension (x-axis); and *internal organizational capabilities* and the *socioeconomic environment* in the second dimension (y-axis).

The heuristic helps to classify business model attributes as structural or cultural, as well as being related to the external socioeconomic environment or internal organizational capabilities, which allows addressing the above discussed internal and external barriers. The authors find that, for example, in the socioeconomic environment structural aspects such as financial market support for sustainability or revised tax systems which sanction negative externalities are crucial. Approaches referring to waste and emission reduction by means of closed-loop systems are boundary-spanning as they connect external and internal structural attributes. Important socioeconomic-cultural aspects are community spirit, stakeholder and shareholder engagement, whereas a long-term focus on business operations is also an internal as well as external capability.

Whereas authors from the technological innovation stream see business models as market devices to support innovations, Birkin and colleagues as well as Stubbs and Cocklin discuss sustainable business models as an expression of organizational and cultural changes in business practices and attitudes that integrate needs and aspirations of sustainable development as formulated in the Brundtland definition or other concepts such as ecological modernization.

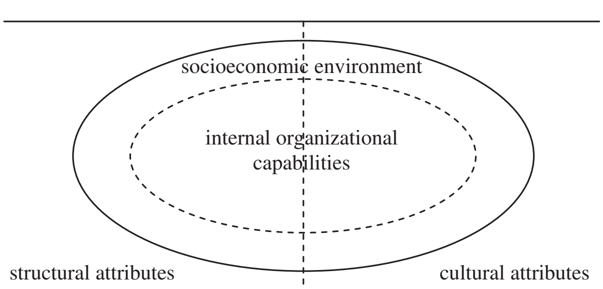

Fig. 1. Dimensions of the "sustainability business model" heuristic (Stubbs and Cocklin, 2008, p. 114).

Business model change on the organizational level is about the implementation of alternative paradigms other than the neoclassical economic worldview that shape the culture, structure and routines of organizations and thus change the way of doing business towards sustainable development; a sustainable business model is the aggregate of these diverse organizational aspects.

4.3.3. Social innovation

A third stream of literature deals with business models related to social value creation. Authors from this stream are inspired by the remarkable achievements of companies like Indian microfinancing pioneer Grameen Bank or Sekem Group, a multibusiness organization specialized on the production of cotton and host of diverse social ventures in Egypt (e.g., Seelos and Mair, 2005, 2006). These models are discussed in the context of the recently emerging concept of social entrepreneurship (SE) that embraces different approaches such as "bottom of the pyramid" (BOP) strategies or social businesses (e.g., Dees, 1998a, 1998b; Mair and Martí, 2006; Prahalad, 2005; Prahalad and Hart, 2002; Yunus et al., 2010).

Hockerts and Wüstenhagen (2010) point to the varied meanings of social innovation: One view emphasizes the role of product and process innovations with a social purpose. Another is related to the scope of entrepreneurial and managerial activities, where innovation can refer to founding and further developing social enterprises, company-internal activities ("social intrapreneurship"; Mair and Martí, 2006), or "corporate social innovation" as business/social sector collaboration (Kanter, 1999). Accordingly, the spectrum of actors and organizational forms reaches from single entrepreneurs dedicated to alleviating urgent social problems by means of non-profit but self-sustaining businesses (e.g., Ibrahim Abouleish and Sekem Group, Muhammad Yunus and Grameen Group; Seelos and Mair, 2005, 2007) to multi-national corporations taking the strategic chance of future BOP markets (e.g., Unilever, Danone; Yunus et al., 2010). Social innovation, like environmental innovation, is seen as a key to creating and transforming markets towards sustainable development (see above Hart and Milstein, 1999; Lovins et al., 1999) – and this is where the transformative power of business models comes into play.

Obviously, social innovations can be linked to technological and/or organizational innovations. However, the approaches mentioned here are primarily orientated towards social purposes and missions. While technological innovations are more about "jobs-to-be-done" (Johnson, 2010) and organizational innovations are a form of corporate self-reflection, social innovations are providing solutions to problems of others, i.e., of societal groups that lack the resources or capabilities to help themselves.

The most prominent research topics, besides theorizing and case studies on the concept of social entrepreneurship, are those linked to the provision of market access and market creation in BOP contexts (e.g., Seelos and Mair, 2005, 2007; Thompson and MacMillan, 2010; Wu et al., 2010). Here, the challenge of SE is to change the value creation logic while human, financial and political resources must be acquired and managed under precarious conditions and high uncertainty (cf. Thompson and MacMillan, 2010). Changing the focus of value creation is thus the primary purpose of business model management and innovation. Whereas social benefits such as employment and access to products and services are by-products of conventional economic value creation, earning money becomes a by-product or condition of social value creation through SE (Seelos and Mair, 2005). The premise is to develop self-sustaining instead of profit maximizing businesses, giving space to entrepreneurs and managers to focus their business models on social issues (see Box 4 for an example).

Box 4. Grameen Telecom – a social enterprise model.

The "*Grameen telephone ladies*" are a good example of a business model for social innovation (Yunus et al., 2010). Grameen Bank offers micro-credits to persons who could never borrow from commercial banks due to a lack of collateral (Seelos and Mair, 2005). Telephone ladies use these loans to buy mobile phones and airtime. Then, they sell airtime to anybody who wants to make a call but cannot afford an own telephone. At the time this model started, 80,000 Bangladesh villages did not have telephone service, i.e., the 300,000 telephone ladies brought electronic communication to the rural and poor population. Despite its initial success this model has reached obsolescence: As cell phones and airtime become more and more affordable to the Bangladeshis, the telephone ladies' market has shrunk significantly (Schaffer, 2007). Nevertheless, the telephone ladies provided valuable insights into the dynamics of social business models in developing countries.

This all is not to say that SE business models exclude any profit orientation. Quite the opposite, as Thompson and MacMillan (2010) see both social and economic profits as conditional for large corporations' engagement in SE initiatives. The crucial point here is the expected magnitude of business model change. As long as social entrepreneurs aim for economic profits (e.g., to pay dividends to shareholders) they may be able to apply rather modified conventional models. But the more the social value creation function is focused, the more will SE result in so called social businesses (a not-for-profit sub-category of SE; Yunus et al., 2010). Yunus and colleagues reason that for social businesses a specific business model framework is needed (Fig. 2) that integrates a social profit equation – whereas the environmental dimension is also recognized (the basic framework includes three elements only: value proposition, value constellation, economic profit equation; e.g., Schoettl and Lehmann-Ortega, 2011).

According to their concept, social businesses apply business models that above all recover their full costs and pass profits on to customers who shall benefit from low prices, adequate services and better access to maximize the social profit equation: "It is a no-loss, no-dividend, self-sustaining company that sells goods or services and repays investments to its owners, but whose primary purpose is to serve society and improve the lot of the poor". (Yunus et al., 2010, p. 311) Not least, the magnitude of business model change depends on the kind of partnership, such as firm/NGO collaboration, which is required to create social value and maximize social profit (Chesbrough et al., 2006; Dahan et al., 2010; Kanter, 1999).

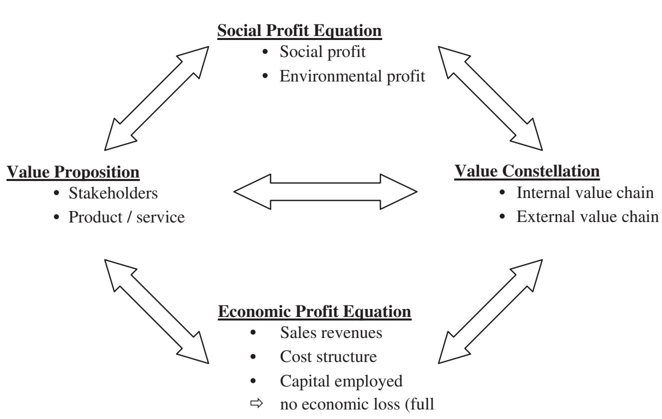

Fig. 2. Components of a social business model template (Yunus et al., 2010, p. 319).

To conclude, sustainable business models enable social entrepreneurs to create social value and maximize social profit; of significance is the business models' ability to act as market device that helps in creating and further developing markets for innovations with a social purpose.

5. Discussion and concluding remarks

Above we have looked at the intersection of two bodies of literature: that on sustainable innovation and the one on business models. We have concluded that the former tends to disregard the precise ways in which firms connect the elements specified by our definition of a business model – the value proposition, organization of supply chain and customer interface, and financial model. In contrast, the firm is often treated as a black box on which external factors impinge, or only specific internal factors are analyzed. At other levels of analysis, elements of the business model are present (especially the organization of the value chain and the value proposition), but without being connected to the firm and mostly leaving out the revenue model. This confirms our idea that the business model concept may help to bring these elements into the research on sustainable innovation.

Hence, one result from our literature review is that the business model of a company, whole industry or business philosophy is seen as a mediator for innovations that not only links production and consumption but also embraces stakeholders and their expectations from non-business areas. These features support the interpretation as a market device (Doganova and Eyquem-Renault, 2009). Moreover, the proposed principles for sustainable business models can be developed further by embedding them into these insights.

For a sustainable *value proposition* business-society dialogs must identify trade-offs between optimal product and service performance (e.g., convenience, low costs) and improved social and environmental effects (e.g., de-materialization, better working conditions). A balanced fulfillment of customer needs will likely require enhanced offerings of which profits are insecure during implementation (e.g., product-service-systems such as Interface's floor-covering service-leasing; see also Charter et al., 2008). Such balancing is highly context-sensitive, as studies in social and organizational innovation reveal.

Barriers to such enhanced offerings are often found in *supply chain* dependencies and locked-in infrastructures (e.g., Wells, 2008; Wüstenhagen and Boehnke, 2008). But Interface shows that transformed product-service models can reduce ecological pressure throughout the supply chain and promote profitable recycling and closed-loop systems (e.g., Lovins et al., 1999; Wells and Seitz, 2005), while the Grameen experience shows that sometimes unforeseen but highly effective supply chains evolve on their own (Yunus et al., 2010).

This shows that the *customer interface* can be addressed very differently, either by means of linear mass-production (Wells, 2008), or in processes of value co-creation or consumer co-production which intensify the producer-consumer relationship. Marketing science recognizes different intensities of cooperation and consumers' motivation to take over responsibility (from community tools such as Wikipedia to product design) (e.g., Etgar, 2008; Payne et al., 2008). These insights should be adapted to enable sustainable value propositions.

Finally, *financial models* must shift from "price-per-unit" to pricing the "job-to-be-done", i.e., focus on the fulfillment of needs instead of selling amounts of products (see Johnson, 2010; Johnson et al., 2008). Job-oriented pricing would be in line with approaches such as de-materialization through product-service-systems (e.g., Halme et al., 2007; Lovins et al., 1999; Tukker and Tischner, 2006).

As mentioned above, the three distinguished innovation categories are interlinked phenomena. While our conclusions from the literature on technological and social innovations emphasize a business model's ability to support technological or social offerings, products and/or services, organizational innovations are more about cross-cutting structural and cultural preconditions within and around companies. Birkin et al. (2009a, 2009b) emphasize the role of management concepts and tools to integrate sustainability-relevant information as well as to maintain legitimacy and legality in the face of increasing stakeholder demands derived from the vision of sustainable development. Stubbs and Cocklin (2008) go even further and ask how a company can be grounded on alternative paradigms other than the neoclassical economic worldview. Here, the search for business models for sustainable innovation turns into the search for another business model for our capitalist society.

6. Towards a research agenda on sustainable business models and innovation – five key issues

Without doubt, the design and management of sustainable business models is an important but yet insufficiently researched area. Therefore, our main contribution is to show how business models and sustainable innovations are interrelated in the current literature; a gap we identified in the first two sections of this article. Second, we contribute to closing this gap as we propose exemplary normative requirements under which business models for sustainable innovation should operate. A first attempt to connect the business model perspective to already established concepts such as corporate sustainability or sustainable innovation. The third contribution is to reflect our findings and ideas in order to offer a starting point for a more focused research agenda.

Therefore we present a number of guiding questions for future research. These are intended to help building a research agenda on business models and sustainable innovations. We suggest thematic avenues for future research, which, in following steps, will require the specification of according research methods and theoretical perspectives. Setting this agenda might start with the fundamental question if and to what degree today's companies are already implementing the normative requirements we formulate in Section 4.1. Empirical research, e.g., following a case study approach, will be needed to shed some light on the state-of-the-art of corporate sustainability management, sustainable organizational development and sustainable innovation in daily business (e.g., Tukker et al., 2008; Stubbs and Cocklin, 2008). Thus, our first guiding question is:

To what extend do firms consider the normative requirements for sustainable business models in their innovation practices – be it process-, product-, or system-oriented?

In part this question is currently taken into account in research on sustainable supply chain management. There is substantial literature on how supply chains are reorganized in the process of making them more sustainable (e.g., Boons and Mendoza, 2010; Seuring and Müller, 2008; Vermeulen and Seuring, 2009). This captures two elements of the business model as defined above, i.e., the organization of links between the firm and its suppliers and customers. It would be interesting to broaden the scope of the supply chain literature in such a way that the other elements of the business model (financial model and value proposition) are also incorporated into the analysis. This leads to our second guiding question:

How do firms connect the four elements of a business model to their innovation attempts?

We find the business model concept helpful in connecting insights at the different levels of analysis that we have identified in the context of sustainable innovation. Business models require a systemic perspective, but always from the viewpoint of how the firm can connect to, or build up, that system while delivering a certain value proposition. System innovation is seen as a crucial strategy to implementing sustainability into wider socio-technical systems (e.g., Charter et al., 2008; Geels, 2005; Johnson and Suskewicz, 2009). Hence, our third question captures this insight:

To what extend do business models allow for sustainable system innovations, and how does this relate to business success?

A related question deals with the extent to which business models allow, or hamper, specific types of innovations (e.g., Johnson, 2010). More specifically:

Is there a relationship between the magnitude of improvement of an innovation and the lock-in provided by the existing business model?

The emphasis of Doganova and Eyquem-Renault (2009) on business models as a market device points out that it does not necessarily make sense to try and pin down the exact business model. When a business model serves to build linkages among actors that are necessary to successfully market a sustainable product or service, various elements being open to multiple interpretations is an asset rather than a problem. In other words, the often lamented "vagueness" of the concept of sustainability may sometimes be a useful quality in bringing about sustainable innovations (e.g., Boons, 2009; Hansen et al., 2009; Tukker and Tischner, 2006; Tukker et al., 2008). This is in sharp contrast with the attempts to define, once and for all and objectively, the sustainability of an innovation. This insight suggests that the way in which sustainability is constructed by actors involved in value creation is an important topic for research (Boons and Mendoza, 2010):

How does the definition of sustainability, as constructed by business model stakeholders, compare to sustainability measures as employed by evaluators of sustainable innovations?

Being aware that our deductive approach is far from delivering a complete, all embracing concept, we aim to direct part of the exponentially increasing work on business models towards a systematic (and systemic) inclusion of sustainability-related business challenges. On the more practitioner-oriented side, business management authors like Porter or Johnson are driving this change (e.g., Eyring et al., 2011; Johnson and Suskewicz, 2009; Porter and Kramer, 2011). To make the topic of sustainable business models become more than rhetoric we suggest drawing some lessons from the topical articles and projects that can be identified today. Therefore, even if it is too early to discuss further aspects such as methodical issues, we would like to start an open process of developing a research agenda that integrates the crucial aspect of creating sustainable value through business models for sustainable innovation.

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Business cases for sustainability: the role of business model innovation for corporate sustainability

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Abstract: A considerable body of literature deals with the creation of economic value while increasing corporate environmental and social performance. Some publications even focus on the business case *for* sustainability which aims at increasing corporate economic value *through* environmental or social measures. The existence of a business case for sustainability is, however, mostly seen as an ad hoc measure, a supplement to the core business, or simply a coincidence. As a contrast, this paper argues that business model innovations may be required to support a systematic, ongoing creation of business cases for sustainability. A framework for business model innovation is proposed as a means to strategically create business cases on a regular basis as an inherent, deeply integrated element of business activities.

Keywords: business case for sustainability; business case drivers; business model for sustainability; sustainability innovation, radical innovation; corporate sustainability; corporate social responsibility; CSR; sustainability strategies; proactive environmental strategies; strategic management; framework; conceptual model.

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1 Introduction

Companies have without doubt a large influence on the economy and life in general. No sustainable development is possible without a sustainable development of corporations. Corporate management is therefore a crucial actor in shaping the future development of companies as well as the economy and society. Management activities are based on managerial decisions derived from reference points such as corporate visions and strategies which shape the business model and the organisational development of a company. Unsustainable management decisions neglecting social and environmental issues impede the whole corporate organisation from improving in sustainability terms. Corporate sustainability strategies are thus of crucial importance to sustainable development but also for successfully directing a company through sustainability-related social, legal, political and economic requirements under conditions of market competition.

The fact that companies are founded and run for economic purposes requires management to develop most of its societal engagement in relation to the economic goals of the corporation. Corporate sustainability strategies are therefore challenged to recognise both, economic sustainability as well as social and environmental sustainability equally (Parnell, 2008). To achieve this integration is the target and purpose of a business case for sustainability.

This paper proposes that a business case for sustainability can be created by addressing business case drivers. It furthermore argues that to strategically create business cases (plural!) for sustainability on a continuous basis, requires an innovative business model which supports the management of voluntary social and environmental activities in addressing the business case drivers in a systematic manner. To achieve this, it can be necessary to adapt or even radically change a company's business model. Engaging in business model innovation aims at unfolding the full potential of these drivers in terms of business success and contributions to sustainable development.

This paper is structured as follows. After a discussion of what can be understood by a business case for sustainability (Section 2), business case drivers are discussed with regard to sustainability (Section 3). Section 4 deals with the role the business model and strategy can exert on the creation of business cases. This analysis provides the basis to discuss business model innovation as a strategic driver for the systematic ongoing creation of business cases for sustainability (Section 5). Finally, Section 6 introduces a business case framework that integrates corporate sustainability strategies, business case drivers, and business model innovation. The discussion in Section 7 summarises the core findings of this paper and highlights the framework's strengths and weaknesses.

2 What is a business case for sustainability?

A business case, or what scholars in business ethics often call 'enlightened self-interest' [see e.g., Carroll, (1991), p.43; Frederick, (1978, 1994), p.151; Garriga and Melé, (2004), p.53; Mintzberg, (1983), p.4; Tracey et al., (2005), p.330], is mostly described by a situation where economic success is increased while performing in environmental and social issues. The role of creating a business case of sustainability has been discussed for many years from various perspectives (e.g., Dyllick and Hockerts, 2002; Epstein, 2003; Holliday et al., 2002; Perceva, 2003; Schaltegger, 2011; Schaltegger and Wagner, 2006; Steger, 2004). One strand of literature is whether creating business cases of sustainability is sufficient to achieve corporate sustainability and sustainable development (Dyllick and Hockerts, 2002). Another strand elaborates on the question whether environmental and social activities and performance are only a side effect of pure economic rationality (e.g., Eden, 1994). Corporate sustainability "is promoted if profitable, for example, because of an improved reputation in various markets" [van Marrewijk, (2003), p.102].

This paper focuses on a third strand which deals with links between voluntary environmental and social activities and corporate economic success, and how these links can be managed, advanced, or innovated in order to improve economic success *through* voluntary social and environmental activities. This is what we call the business case *for* sustainability.

On a general level, the link between environmental and economic performance has been a topic of debate in the literature for more than 15 years (see e.g., Burke and Logsdon, 1996; Edwards, 1998; Griffin and Mahon, 1997; Hamilton, 1995; Heinze et al., 1999; Margolis and Walsh, 2003; Pava and Krausz, 1996; Porter and van der Linde, 1995a, 1995b; Russo and Fouts, 1997; Wagner and Schaltegger, 2003). Whereas in the beginning most of the debate was about whether a positive link or a business case exists or not (see e.g., Esty and Porter, 1998; Hart and Ahuja, 1996; Reinhardt, 1999), research has shifted for the last couple of years towards the question what kind of links exist between voluntary environmental and social engagement and business success (see e.g., Griffin, 2000; Holme and Watts, 2000; Lankoski, 2000, 2006; Margolis and Walsh, 2003; Martin, 2002; Pearce, 2003; Reinhardt, 2000; SustainAbility, 2001; Wagner et al., 2002; Wagner, 2007; Wagner and Schaltegger, 2003, 2004).

One conclusion of this research is that it is an illusion to believe that any kind of automatic relationship exists between voluntary societal activities and business success (Schaltegger and Synnestvedt, 2002; Steger, 2004; Wagner, 2007). Theoretical and empirical research indicates that most companies seem to have potential for one or several business cases for sustainability (Schaltegger and Wagner, 2006; Steger, 2004). However, this potential is often not recognised because of distorted accounting and management information systems (Wallmann, 1995; Schaltegger and Burritt, 2000) and other organisational rigidities (Steger, 2004). As a consequence, management is challenged to find approaches to realise potential business cases through adequate sustainability management. A business case for sustainability has to be created – it does not just happen.

A business case *for* sustainability – as a difference to just a conventional business case or a business case *of* sustainability – has the purpose to and does realise economic success through (not just with) an intelligent design of voluntary environmental and social activities. A business case for sustainability is thus characterised by three requirements which have to be met.

Firstly, the company has to realise a voluntary or mainly *voluntary activity with the intention to contribute to the solution of societal or environmental problems*. These are intended activities for the society or the natural environment which are not just a reaction to regulations and legal enforcement or which would be expected for economic reasons as part of conventional business behaviour anyhow.

Secondly, the activity must *create a positive business effect* or a positive economic contribution to corporate success which can be measured or argued for in a convincing way. Such effects can be cost savings, the increase of sales or competitiveness, improved profitability, customer retention or reputation, etc. The cause and effect relationship can be direct or indirect, however, must not be speculative but rather based on a sound business argumentation.

Thirdly, a clear and convincing argumentation must exist that a *certain management activity* has led or will lead to both, the intended societal or environmental effects, and the economic effect. A business case for sustainability is characterised by creating economic success *through* (and not just along with) a certain environmental or social activity.

Considering these three characteristics of a business case for sustainability may provide some explanation for the different views about the role, value and effects of a business case with regard to sustainable development. The question, for example, whether creating business cases is sufficient to achieve corporate sustainability and sustainable development (Dyllick and Hockerts, 2002), is justified if management does not have the initial intention to solve social or environmental problems, if environmental and social activities are only a side effect of pure economic rationality (e.g., Eden, 1994), or if the company just tries to leverage economic performance with coincidental sustainability contributions [van Marrewijk, (2003), p.102]. However, accepting or increasing profit of (coincidental) sustainability activities is fundamentally different from planning and realising voluntary social and environmental activities through which economic performance is created or increased.

To create a business case for sustainability requires strategic management to identify, create and strengthen the links between non-monetary social and environmental activities on the one hand and business or economic success on the other hand. Furthermore, in order to achieve such business cases, the formulation and implementation of corporate strategies have to change, compared to strategies that only strive for ‘market sustainability’ through competitive advantages in the sense of the resource-based theory of the firm, for example (cf. Parnell, 2008; Stead and Stead, 2008). That is, strategic objectives and measures, and sometimes even the business model of a firm, have to be oriented towards a triple bottom line (e.g., Elkington, 1998; Norman and MacDonald, 2004). Based on these key assumptions this paper asks how strategic sustainability management can contribute to create and manage business cases for sustainability, what drivers it has to address in order to create a business case for sustainability, and how business model innovation can serve as a framework for this endeavour.

3 Drivers of business cases for sustainability

3.1 The link between voluntary societal activities and corporate economic success

To discuss and manage business cases for sustainability requires some understanding of the relationship between voluntary societal activities and corporate economic success (e.g., Schaltegger and Synnestvedt, 2002). Various models have been proposed to analyse these links theoretically and empirically (for overviews see e.g., Salzmann et al., 2005; Schaltegger and Wagner, 2006).

Earlier work mostly assumed that the optimum level of environmental or social performance for a firm may be just achieving legal compliance with regulation. This 'traditionalist' view argues that firms face a trade-off between (better) environmental or social performance on the one hand and (worse) economic performance or competitiveness on the other (e.g., Wagner, 2007; Walley and Whitehead, 1994; Palmer et al., 1995; Simpson and Bradford, 1996; Xepapadeas and de Zeeuw, 1999).

Whereas reactionary people maintain that any kind of voluntary activity outside the narrower focus of economic measures will hamper profit [Hemphill (1997) calls this perspective the 'minimalist' view], modernist and innovative observers of business reality will find examples of profit increasing or business supporting measures. Most of the more recent research on the links between voluntary sustainability measures and corporate economic success emphasises the possibility of win-win or triple-win potentials (e.g., Eyring et al., 2011; Holme and Watts, 2000; Lankoski, 2000, 2006; Margolis and Walsh, 2003; Martin, 2002; Pearce, 2003; Porter and Kramer, 2011; Reinhardt, 2000; Schaltegger and Synnestvedt, 2002; SustainAbility, 2001; Wagner et al., 2002; Wagner, 2007).

Examples can of course be found for both effects: end-of-pipe measures creating costs and reducing profitability as an example for profit-decreasing measures and the sales success and profitability of green products as example for profit-increasing measures. The economic return of a certain environmental or social performance will vary whether cost-driving or profit-driving activities have been chosen and designed.

In other words, there is no general answer to whether it pays to be green (e.g., Reinhardt, 1999, 2000; Schaltegger, 2011), but it is rather a management challenge to create societal engagement in a way that it contributes to business and economic success. It depends on what kind of measures is chosen. A business case for sustainability has to be created and managed – it does not just happen.

The fact that business case potentials are often overseen, even by well-informed corporate professionals, and the necessity to identify and analyse business case potentials and to manage them in a structured way is maybe most apparent in production where cleaner production approaches have had difficulties to spread on a wide basis for the last decades even in companies with large cost saving potentials (e.g., Montalvo, 2008; Montalvo and Kemp, 2008). Furthermore, sustainability potentials are often overseen due to a lack of integration with processes of strategy formulation and, related to this, due to lock-in effects of established company business models which set boundaries to variations of corporate behaviour (e.g., Johnson, 2010).

However, even if the most profitable measures are chosen, the success will at some point have its culmination and decline because no company will have an unlimited number of profit-increasing voluntary social or environmental activities in a given business model (Schaltegger and Synnestvedt, 2002). The core question and the basis for any management of a business case for sustainability is thus how profit increasing societal activities, rather than cost increasing measures, can be identified and integrated with the core business approach of a company. This is where managing a business case for sustainability links in with strategic sustainability management and business model innovation (see e.g., Porter and Kramer, 2011). The first linking step is the discussion of drivers of a business case.

3.2 Drivers of business cases

The drivers of a business case for sustainability are variables which directly influence economic success and therefore are related to the drivers of a conventional business case [for an overview of performance drivers see Olve et al. (1999)]. The *links* between voluntary sustainability activities and economic success, however, are often different to conventional economic cause-and-effect relationships and therefore also the kind of influence a social or environmental activity has on the economic drivers.

Reviewing the literature reveals business case drivers on a wide range from direct to indirect influence on economic performance. The most direct link may be through *costs*. The role of costs and cost reduction (see e.g., Christmann, 2000; Epstein and Roy, 1996) is often addressed as a driver with regard to energy savings, the reduction of material flows (e.g., Jasch, 2008) or cleaner production. Another commonly mentioned driver which is related to contingencies, potential and actual costs, is the reduction of technical, political, societal and market *risks* (e.g., Schaltegger and Wagner, 2006) as a result of good sustainability management. Opportunity-oriented drivers of business cases for sustainability are addressed when *sales and profit margins* (e.g., Porter and van der Linde, 1995a, 1995b) or the company's *reputation and brand value* (e.g., Jones and Rubin, 1999; van Marrewijk, 2003) are increased. Furthermore, other drivers such as market entry or development can play an important role depending on the circumstances and the company's strategy (e.g., Porter and van der Linde, 1995b). Apart from these drivers with a rather direct economic impact, some authors discuss more indirect economic effects driven by the influence of corporate sustainability. One is the *attractiveness as an employer* (see e.g., Ehnert, 2009; Revell et al., 2010) which can be driven through recruiting and selection, induction and development programmes [Hansen, (2010), pp.109–115]. Another is the *capability to innovate* which sustainability can improve because thinking in diverse dimensions is encouraged and more diverse knowledge sources – e.g., from fringe stakeholders – are sought (see e.g., Cohen and Winn, 2007; Pujari, 2006; Schaltegger and Wagner, 2011). In summary, the core drivers of a business case for sustainability are presented in Table 1.

All voluntary social and environmental projects and activities can be analysed in terms of their influence on these drivers. Current *empirical* research shows that these six main drivers are by no means randomly compiled. For example, Hansen (2010, p.29) in a meta-analysis of four German studies finds that reputation, risks, attractiveness as employer and the capacity to innovate for new products and services were the most important drivers for sustainability engagement. In an SME context, Collins et al. (2010) identified reputation and brand, employees' demands, risk management and potential cost reductions as most important drivers to be recognised when adopting environmental and social initiatives in companies in New Zealand. Further, Revell and colleagues found similar drivers in their empirical research on SMEs in the UK (Revell and Blackburn, 2007; Revell et al., 2010). Their sample data from 2006 and 2007 illustrates that at this time owner-managers were still somehow sceptical about the potential to create business cases based on positive environmental contributions. Still, at the same time, Revell et al. (2010) identify the drivers that might contribute to business success when striving for environmental reform in business: cost reductions (e.g., through resource efficiency) are seen as the most promising driver, followed by aspects such as dealing with regulatory risks, attracting and retaining staff, attracting new customers and increasing market share, as well as attaining good publicity.

Table 1 Core business case drivers for the business case for sustainability

Core business case drivers	*Exemplary authors*
Costs and cost reduction	e.g., Christmann (2000), Epstein and Roy (1996)
Risk and risk reduction	e.g., Schaltegger and Wagner (2006)
Sales and profit margin	e.g., Porter and van der Linde (1995a, 1995b)
Reputation and brand value	e.g., Jones and Rubin (1999), van Marrewijk (2003)
Attractiveness as employer	e.g., Ehnert (2009), Revell et al. (2010)
Innovative capabilities	e.g., Cohen and Winn (2007), Pujari (2006), Schaltegger and Wagner (2011)

An important issue which is often neglected when assessing the business or economic effect of environmental and social activities is that their path of influence (or cause-and-effect link) can be quite indirect, involving non-market links and actors such as political initiatives, and NGOs. In addition, these relationships can be stochastic which makes their management more difficult (e.g., Edwards, 1998; Griffin and Mahon, 1997; Lankoski, 2000, 2006; Salzmann et al., 2005). The variety of possible relationships and the different character of sustainability issues requires firstly to distinguish different strategic positions towards integrating the societal and environmental dimensions with business (e.g., Aragón-Correa and Rubio-López, 2007; Bhimani and Soonwalla, 2005; Epstein, 2003; Parnell, 2008; Schaltegger and Wagner, 2011) and, secondly, to clarify if and how specific socially or environmentally relevant activities influence the business model of a firm (e.g., Birkin et al., 2009a; Eyring et al., 2011; Porter and Kramer, 2011; Stubbs and Cocklin, 2008). This provides a basis for the discussion of links between business cases for sustainability, sustainability-oriented strategies, and business model management.

4 From business cases to business models for sustainability

4.1 The business model as a platform for creating business cases for sustainability

A business model of a company is a somehow elusive idea of how business is conducted in order to create and capture economic value (e.g., Mäkinen and Seppänen, 2007; Teece, 2010; Zott et al., 2011). Neither theoretical nor empirical research offers sufficient answers to the question what a sustainable business model might be (e.g., Schaltegger and Wagner, 2011; Stubbs and Cocklin, 2008). Besides that the term of a business model is still developing, the integration of the business model with sustainability evokes significant conceptual challenges: the integration of economically relevant sustainability aspects with corporate business success is a multidimensional task (e.g., Hansen et al., 2009; Stead and Stead, 2008; Schaltegger, 2011; Wagner, 2007). Furthermore, mapping the links between business models and business cases for sustainability may be worthwhile to get from single and event-driven business cases for sustainability to business models for sustainability, which serve as templates for reproducing the respective business cases on a regular basis. In other words, moving from single to continuous business case creation may be supported by a business model rationale which positions sustainability as an integral part of the company's value proposition and value creation logic.

Theoretical considerations suggest that various approaches to *integrating* sustainability aspects into a business model as well as *extending* it should exist and that these should be directly related to the degree to which environmental and social aspects have become ingrained into the corporate sustainability strategy that underlies the business model (Lüdeke-Freund, 2009). In general, it seems obvious that as environmental and social issues gain relevance in the strategy, more extensive changes of the business model have to be conducted. This can include both modifications of existing models as well as the development of new ones from sketch. This – as argued later – are different degrees of business model innovation.

In the conceptual framework proposed here, the business case drivers have the character of intermediating variables which link the corporate sustainability strategy with the 'architectural' business model level of a firm [for general interrelations between business strategy and business architecture see e.g., Osterwalder (2004) and Teece (2010)]. To map the links between business case drivers, corporate sustainability strategies, and business models, the following three questions are crucial:

- Does a corporate sustainability strategy comprise activities and projects which explicitly address the business case drivers?
- Does the way of addressing these drivers conform to the characterisation of a business case for sustainability?
- Does the way a corporate sustainability strategy addresses business case drivers lead to or require business model innovations in order to achieve economic success?

To offer a management approach that identifies the crucial links between the drivers of a business case for sustainability, the corporate sustainability strategy and the business model, two types of interrelations have to be characterised: first, links between corporate sustainability strategies and business case drivers, and, second, links between business case drivers and the business model. Thus, management decisions can be supported by answering the question whether a business case for sustainability requires a modified or even a completely new business model.

4.2 Links between corporate sustainability strategy and business case drivers

Various taxonomies and typologies of sustainability strategies have been established representing a continuum ranging from defensive to proactive approaches. Though also other early advances exist (e.g., McAdam, 1973; Davis and Blomstrom, 1975; Miles and Snow, 1978), the scale proposed by Wilson (1975) often serves as a point of orientation for managerial approaches and receives wide acceptance amongst scholars in the area of sustainability and CSR [see e.g., Azzone and Bertelè (1994), Carroll (1979), Henriques and Sadorsky (1999), Roome (1992), and Wartick and Cochran (1985); for a more detailed review of taxonomies and typologies, see Buysse and Verbeke (2003)]. He defines *reactive*, *defensive*, *accommodative*, and *proactive* postures of responsiveness (Wilson, 1975), a continuum which Henriques and Sadorsky (1999) also call the 'RDAP scale'. As the reactive strategy entirely neglects environmental and social issues, only the three strategy types defensive, accommodative, and proactive are helpful in analysing strategy and business case driver interrelations.

These three strategies are related to the above introduced business case drivers as follows [similar links between corporate performance and environmental strategies were established by, for example, Aragón-Correa and Rubio-López (2007), Henriques and Sadorsky (1999), and Roome (1992)]:

- *Defensive (limited integration)*: Defensive strategic behaviour is often a reaction on (perceived) cost-constraints. Managers deal with sustainability issues in a rather narrow, reactive manner. The main motivation behind defensive strategies is not to gain competitive advantage with sustainability performance, but the need to comply with legislation [also termed 'compliance strategy'; Roome, (1992), p.18]. Defensive strategies are directed towards the protection of the existing business and revenue generating rationale ('business logic'; Prahalad and Bettis, 1995). Efficiency and cost-related aspects are addressed as well as communication and public relations to reduce reputational and legislative risks.
- *Accommodative (integration)*: This strategy reflects a rather cautious modification of internal processes and the modest consideration of environmental or social objectives such as environmental protection, eco-efficiency, or occupational health and safety. Managers are willing to use sustainability management systems and tools to control the organisation and are partly aware of the need for organisational change which requires some involvement and training of employees [comparable to Roome's (1992, pp.18–19) 'compliance-plus strategy']. Overall, accommodation strategies integrate environmental or social objectives in most of the business processes and maybe partly in the product range, however, without questioning the revenue logic or the core business as such.
- *Proactive (full integration)*: Proactive strategies integrate environmental or social objectives as part of the core business logic in order to contribute to sustainable development of the economy and society. The core business and thus all business processes and the full product range are directed towards sustainability, as is the revenue logic. Therefore, central concepts such as the definitions of costs and risks are modified to account for negative externalities (i.e., social costs and risks). Efficiency and cost-related aspects are addressed as well as customer issues, sustainability-oriented innovation capabilities and societal 'non-market' issues. A proactive strategy pursues business and sustainability goals simultaneously and strives for business leadership through outstanding sustainability performance [this refers to what Roome (1992, p.19) calls 'commercial and environmental excellence' and 'leading edge'].

Table 2 Interrelations between corporate sustainability strategies and business case drivers

	Corporate sustainability strategy		
Core drivers of business cases for sustainability	*Defensive*	*Accommodative*	*Proactive*
Costs and cost reduction	Mainly cost and efficiency-oriented compliance activities (often 'low hanging fruit' only)	Cost and efficiency-oriented activities actively pursued and linked to sustainability issues when possible	Cost and efficiency-oriented activities actively created to achieve sustainability goals; cost concept includes external social costs
Risk and risk reduction	Sustainability issues seen as sources of risk; activities aim at risk reduction (in contrast to precaution)	Sustainability and risk management seen as complementary and opportunity-creating concepts	Sources of high risks are largely removed
Sales and profit margin	Products or product communication are adapted to reduce risks of sales decrease; cause-related marketing to 'attach' a green image to unchanged products	Sustainability-oriented customer segments are partly acknowledged and served with specific products (besides existing conventional product lines)	Market-oriented strategies to gain competitive advantage by making sustainability-oriented products and services become the core of the company's portfolio
Reputation and brand value	Reputational activities, rather reactive and mainly oriented towards risk reduction	Sustainability activities have limited potential to contribute to reputation and brand due to mainly internal focus	Sustainability is actively communicated and is a major driver of reputation and brand value; the company engages in boundary-spanning and stakeholder integration
Attractiveness as employer	Increased salaries to retain and attract personnel	Sustainability engagement (and related communication) partially increases attractiveness to some groups of employees and talents	Continuous education, innovative positions, social attention (e.g., towards families) increase attractiveness to highly skilled workforce and new talents due to high sustainability reputation
Innovative capabilities	Innovations to obscure non-performance with regard to sustainability (e.g., 'greenwashed' products)	Process, product, and organisational innovations limited by boundaries of existing business logic	Sustainability-oriented process, product, and organisational innovations transform business logic; sustainability problems and stakeholders are considered a key source of innovation

As can be seen from Table 2, different sustainability strategies put different emphases on the individual business case drivers. Consequently, every sustainability strategy is supposed to affect the business model of a company differently. Before mapping the links between strategy and business model (which is an ongoing and controversial debate amongst strategy scholars; e.g., Casadesus-Masanell and Ricart, 2010), the latter has to be linked to the business case drivers. Based on these links, every modification or development of the business model with the strategic intention to support voluntary environmental and social activities contributing to these drivers can be regarded as an approach towards a business model for sustainability.

4.3 The links between business model and business case drivers

Progress in corporate sustainability is an entrepreneurial and managerial venture based on normative goals and strategies which have to be translated into practical operations through adequate concepts and instruments (see e.g., Schaltegger and Burritt, 2005; Schaltegger and Wagner, 2006). The above outlined interrelations between corporate sustainability strategies and the business case drivers illustrate some of the complexities of managing this translation. Going one fundamental step further raises the question of how to change the existing (i.e., dominating) business logic of a company which creates the foundation for the strategy and business case interrelationships. Transforming the business model is a common theme in strategic management and organisation studies (several 'mainstream' authors address this topic from a business model perspective; see e.g., Chesbrough, 2007, 2010; Johnson, 2010; Johnson et al., 2008; Mitchell and Coles, 2003, 2004a, 2004b; Teece, 2010). To study the links how different business models and strategies influence the generation mode of business cases for sustainability is thus a strategic challenge (only a limited number of authors deal with this type of sustainability-oriented organisational change; see e.g., Birkin et al., 2009a, 2009b; Stubbs and Cocklin, 2008).

Two different causalities between sustainability strategies and the business model may be considered. First, if a company implements a strategy aiming at the business case for sustainability the business model may have to change (directly or indirectly). In other words, the need to develop and activate business case drivers (e.g., the need to improve cost structures due to more expensive but environmentally friendly production inputs) may require changes of the business model configuration (see Table 3). Second, and vice versa, the business model also determines and constrains corporate strategy and the business case for sustainability. The business model is often interpreted as a determining factor of corporate behaviour and thus business opportunities [e.g., Baden-Fuller and Morgan, 2010; Chesbrough, 2010; Wirtz, 2011; Yip, 2004; Zott et al., 2011; see also Elkington (2004), who calls the business model the 'DNA of business']; i.e., the business model in turn influences business strategy and operative outcomes (such as cost structures).

In other words, a company which tries to improve its sustainability performance has to change its business model, however incremental or radical, which can turn out to be *the* decisive (i.e., limiting or supporting) factor for succeeding in creating one or many business cases for sustainability [concerning different intensities of business model innovation see e.g., Chesbrough (2007, 2010), Mitchell and Coles (2003), and Yip (2004)]. Despite the fundamental significance of business models, besides some anecdotal evidence (Hansen et al., 2009) and early works which apply a very broad understanding of business models (e.g., Stubbs and Cocklin, 2008), the business model has been mostly neglected in academic and practitioner-oriented literature on corporate sustainability and corporate sustainability management.

Therefore, in order to map out interrelations between business case drivers and the business model, a general business model concept has to be introduced. Four central pillars can be identified when reviewing relevant literature [Ballon, (2007), p.8; emphases added]:

- "the products and services a firm offers, representing a substantial value to a target customer (*value proposition*), and for which he is willing to pay
- the relationship the firm creates and maintains with the *customer*, in order to satisfy him and to generate sustainable [here: long-term] revenues
- the *infrastructure* and the network of partners that are necessary in order to create value and to maintain a good customer relationship
- the *financial aspects* that can be found throughout the three former components, such as cost and revenue structures."

From a strategic management perspective, a business model primarily focuses on the value created for customers (e.g., Wirtz, 2011). Therefore, a company has to manage its partnerships, activities, and resources, i.e., its infrastructure, to offer adequate value configurations for products and services, whereas activities and resources are both company-owned and acquired from partners (e.g., Amit and Zott, 2010; Zott et al., 2011). To address customer segments communication and distribution channels as well as diverse customer relationships have to be established. Finally, the financial aspects refer to optimising revenue streams from customers as well as infrastructure costs in order to appropriate economic value for the company (e.g., Osterwalder, 2004). Osterwalder's business model concept was among the first to include a thorough definition and a representation based on these four pillars and their relationships (ibid.); meanwhile, variations of this concept can be found throughout the present literature (e.g., Johnson et al., 2008; Johnson, 2010; Wirtz, 2011; Chesbrough, 2010).

Understanding these four pillars is crucial for managing a business model and it is even more important for understanding business model innovation (e.g., Chesbrough, 2010; Teece, 2010; Wirtz, 2011; Zott et al., 2011). Whilst the four business model pillars describe the logic of companies in more general terms, when it comes to *sustainability-oriented* business model innovation it is essential to understand and manage the links between these pillars and the business case drivers – which in turn influence whether a business case is created or not. Table 3 shows possible interrelations between the business model pillars and business case drivers.

As Table 3 shows, the different business model pillars are differently affected by the business case drivers. That is, based on the chosen sustainability strategy, different drivers are addressed which in turn requires different degrees of business model innovation.

Table 3 Interrelations between business model and business case drivers

	Generic business model pillars			
Core drivers of business cases for sustainability	*Value proposition (VP)*	*Customer relationships (CR)*	*Business infrastructure (BI)*	*Financial aspects (FA)*
Costs and cost reduction	Products and services with lower energy or maintenance costs for customers	Cost-efficient contracting relationships, closed-loop service systems	Costs of new products and services can be lowered through partnerships	Balancing cost reductions for customers and cost structures of new products and services to increase profitability
Risk and risk reduction	Lowering societal risks through products and services can create value to certain customer segments	Service-relationships reducing sustainability risks for customers result in higher customer loyalty	Resources, activities, and partnerships set-up in order to minimise internal and external risks	Improved risk and credit rating resulting from lowered sustainability risks
Sales and profit margin	Environmentally and socially superior products and services require modified or new VPs to turn into sales and profits	Higher customer retention and customer value as a result of sustainability-oriented, service-intense relationships	New products and services may require strategic partnerships (e.g., coopetition) to overcome market barriers	New products and services and/or new customer relationships contribute to diversified revenue streams
Reputation and brand value	Sustainability as distinctive element of good corporate reputation	Sustainability as marketing feature of the brand increasing customer loyalty	Strategic partnerships with sustainability leaders can increase reputation and brand value	Sustainability performance leading to a good rating and the consideration in sustainability indices and funds
Attractiveness as employer	A companies' offerings and VPs allowing for personal identification to attract employees	Better customer service as a result of higher employee motivation	Attractiveness as principal can enhance the quality of activities, resources, and partnerships	Reduced costs for HR acquisition, less fluctuation costs and lower compensation costs
Innovative capabilities	Unfolding the full sustainability-potential of innovations enables modified or new VPs	Innovative products and services creating solutions to sustainability problems, improving customer retention	To allow for innovations to unfold may require new activities, resources, and partnerships	Higher innovation potential and expectations for profitable innovations leading to an increase of shareholder value

5 The role of business model innovation

5.1 Introducing business model innovation

Despite the fact that business model research is a rather young field of management studies (e.g., Baden-Fuller and Morgan, 2010; Zott et al., 2011), a broad discourse on business model innovation has evolved for the last decade (e.g., Chesbrough and Rosenbloom, 2002; Chesbrough, 2007, 2010; Mitchell and Coles, 2003, 2004a, 2004b; Demil and Lecocq, 2010; Johnson, 2010; Johnson et al., 2008; Teece, 2010; Zott et al., 2011). According to the literature review conducted by Zott et al. (2011), there is consensus on some core issues of research on business model innovation. Scholars seem to agree that the business model is not only a facilitator of technological and organisational innovations, but can become itself subject to strategic innovation in order to share and leverage resources such as knowledge, managerial and entrepreneurial skills, or to enable reconfigurations of the underlying value chain or value network (e.g., Schweizer, 2005; Wirtz, 2011). From this perspective, the business model is a strategic asset to improve firm performance (e.g., Afuah, 2004; Casadesus-Masanell and Ricart, 2010; Chesbrough, 2007; Hamel, 2000; Magretta, 2002), and, more fundamentally, may define a leadership agenda on strategic business model management and innovation (e.g., Chesbrough, 2010; Doz and Kosonen, 2010; Smith et al., 2010). However, the current discourse widely ignores issues of corporate sustainability [exceptions are e.g., Johnson and Suskewicz (2009) with regard to eco-innovations and Yunus et al. (2010) with regard to social entrepreneurship].

To fill this gap, a basic understanding of what constitutes business model innovation has to be related to corporate strategies, the above defined drivers and the concept of the business case for sustainability. The framework introduced by Mitchell and Coles (2003) provides an appropriate starting point. In a longitudinal study on 100 public companies they analysed that outperforming companies shared one common feature:

> "... it was clear that perennial top performers were frequently making fundamental improvements in several dimensions ... of their business models at once for serving their customers, end users and other important stakeholders (such as employees, partners, suppliers, distributors, lenders, shareholders, and the communities the company serves). The most effective companies were making these multidimensional business model shifts every two to four years."
> [Mitchell and Coles, (2003), p.16]

The most important finding of their study refers to what might be termed a *strategic leverage effect of business model innovation*: in line with Porter (1996), and Mitchell and Coles (2003) identified cost and differentiation strategies to be driving outperformance, whereas the really new insight was that top performers were using business model innovations to amplify their strategic effectiveness. Amit and Zott (2010) draw comparable conclusions from different studies among thousands of CEOs who see business model innovation as top priority compared to product or process innovations which often create only short-term competitive advantages. Amit and Zott (2010) go even further and separate business model innovation completely from product and process innovation. They claim that it is less costly, more effective, and the appropriate approach in times of capital scarcity, such as the latest global economic downturn.

5.2 Degrees of business model innovation

Business model innovation covers changes from incremental adjustments to more radical changes. Mitchell and Coles (2003) propose a classification of business model innovations which distinguishes improvement, catch-up, replacement and actual innovation. As all of these steps of improvement are somehow related to (more or less incremental or radical) innovation, different notions are proposed here to match the purpose of creating business cases for sustainability. Four stages – adjustment, adoption, improvement, and redesign – are differentiated in the following:

- *Business model adjustment* refers to changes of only one (or a minor number of) business model element(s), excluding the value proposition; i.e., modifications of customer relationships, business infrastructure, or the financial pillar alone constitute improvements.
- *Business model adoption* [similar to the 'catch-up' stage proposed by Mitchell and Coles (2003)] refers to changes that mainly focus on matching competitors' value propositions. The goal is to not fall behind market standards and competitors. This requires adoptions of products and/or services, but sometimes also parts of the customer relationships pillar and the business infrastructure as these elements can be part of the value proposition as well (Osterwalder, 2004).
- *Business model improvement* takes place, put simply, when substantial parts of the business model elements are changed [Mitchell and Coles (2003), call this 'replacement', even though the value proposition is not replaced]. That is, simultaneous changes of a major number of elements, such as customer relationship approaches, infrastructure elements such as the business network, and the financial logic are required to replace an existing model. The value proposition, however, stays unaltered.
- *Business model redesign* exists in a focused sense when an improvement leads to a completely new value proposition. While a business model might be improved without changing the value proposition to the market (e.g., shifting from own production to purchasing), a real redesign replaces the underlying business logic and offers new products, services or product-service systems (Devisscher and Mont, 2008). An example is a car manufacturer who develops from a sole product vendor to a mobility provider, for example, by offering car-sharing or even ride-sharing services (Hansen et al., 2010).

The strategic leverage effect of business model innovation increases the effectiveness of business strategies. Against this background, the following section presents an integrated framework by bringing together sustainability strategies (and the related business case drivers) and the four degrees of business model innovation.

6 An integrated framework of sustainability strategy, business case drivers and business model innovation

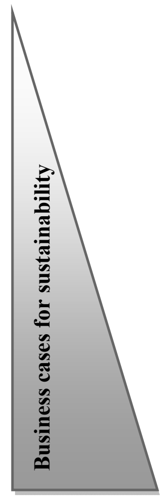
The previous section argued that, firstly, environmental and social activities aiming at business cases for sustainability can be attributed to a continuum of generic sustainability strategies (defensive, accommodative, and proactive). Furthermore, to create business cases these strategies should address, i.e., support, the main drivers of business success (costs and cost reduction, sales and profit margin, risk and risk reduction, reputation and brand value, attractiveness as employer, as well as innovative capabilities; cf. Table 2). Secondly, modifications or even further development of a company's business model may be necessary to fully unfold the business case potential of these sustainability strategies and the drivers they address (cf. Table 3).

Summarising these links, the present section introduces an integrated framework for the business case for sustainability by combining sustainability strategies, the degrees of business model innovation and business case drivers. This framework is intended to help practitioners and researchers to identify how a given sustainability strategy must be combined with a certain degree of business model innovation (cf. Table 4):

- *Defensive strategies* with slight degrees of *business model adjustment or adoption protect the current business model*. They only touch few business case drivers and these in a modest way and thus do not create substantial business cases for sustainability.
- *Accommodative strategies* go along with a change and some *improvement of the business model*, thus exerting some influence on business case drivers *by experimenting within the current model*. The influence of accommodative strategies, however, is less fundamental and lasting than that of proactive strategies.
- As a contrast, *proactive strategies* leading to *(actual) business model redesign* address many business case drivers strongly and continuously, with the effect of regular creations of business cases for sustainability.

The framework should also help to identify possible conflicts between the chosen corporate sustainability strategy and the degree of business model innovation. For example, if an ambitious, proactive sustainability strategy is chosen, but the degree of business model innovation is constrained to a business model adoption (e.g., through green 'me-too' products), frictions will inevitably occur as the business model will be too rigid to fully implement the sustainability strategy and develop the related business case drivers. A textbook example is the greening strategy of Shell, 'Responsible Energy' (e.g., Backer, 2009). Understanding these relationships might help to identify and adjust wrong expectations towards the payoff of social and/or environmental measures, what otherwise would lead to the management's disappointment. Further developing the understanding of these linkages may also help to prevent greenwashing, as it helps external stakeholders to earlier detect dissonances in a company's approach.

Table 4 Framework for business cases for sustainability and integrated business model innovation

Sustainability strategies	*Degree of business model innovation*	*Effects of addressed drivers of business cases for sustainability*	*Contribution to business cases*
Defensive	Business model adjustment* Business model adoption*	Mainly *cost and efficiency-oriented measures* aim for low-hanging fruit and thus only require moderate (if any) business model changes. Accordingly, only a minor number of business elements (excluding the value proposition) are affected. Sustainability issues are primarily perceived as *risks* leading to protective behaviour, while *reputational activities* are of a rather cosmetic nature.	
Accommodative	Business model improvement	*Cost and efficiency-oriented measures* are pursued actively and partly linked to sustainability issues. Together with sustainability-oriented *risk management* this can require very basic changes like renewing production processes, changing value network partners, or approaching new market segments. A general orientation towards external addressees in terms of *reputation, brand, and attractiveness to employees* can require basic changes in customer relationships and business processes.	
Proactive	Business model redesign (in a focused sense)	As proactive strategies feature radical changes to the core business logic of a company, a major number of business model elements will be affected. *Sales and profits* are improved by environmentally and socially outstanding products and services, leading to not yet available value propositions. *Cost and efficiency-oriented measures* are applied to support the new products and services and to gain competitive advantage through sustainability performance, which in turn pays in terms of *risk management, reputation and corporate brand value.* As innovative drivers unfold their full potential the company becomes increasingly *attractive to high-skilled employees.*	

Note: *Mitchell and Coles (2003, p.17), on which this classification is based, themselves reduce the lowest two degrees of business model innovation to one category.

7 Discussion and outlook

A business case *of* sustainability is often described as a situation where economic success is increased while performing in environmental and social issues. As a distinct difference to this view (see Section 2), a business case *for* sustainability is created only if economic success through voluntary social and environmental activities is achieved. Given that such a business case does not happen, but has to be managed actively, core requirements of a business case for sustainability are voluntary social and environmental activities which are based on deliberate management activities to improve sustainability through which a positive economic effect is created.

To deliberately manage business cases for sustainability requires a good understanding of how the drivers of a business case can be positively influenced with societal and environmental activities. The main identified business case drivers are costs and cost reduction, sales and profit margin, risk and risk reduction, reputation and brand value, attractiveness as employer, and innovative capabilities (see Section 3).

Furthermore, sustainable development requires more than coincidental, ad hoc or eclectic creation of a business case now and then. A strategic (i.e., systematic, coherent and continuous) management of business cases for sustainability may rather require a more fundamental change and development of the business model of the company. Investigating the interrelations between the corporate strategy and the drivers of a business case for sustainability on the one hand, and the business model and the drivers of a business case on the other hand supports the argument that business model innovation may be key to create a strategic leverage effect (see Sections 4 and 5).

Based on the understanding of a business *case* for sustainability, a business *model* for sustainability can be defined as supporting voluntary, or mainly voluntary, activities which solve or moderate social and/or environmental problems. By doing so, it creates positive business effects which can be measured or at least argued for. A business model for sustainability is actively managed in order to create customer and social value by integrating social, environmental, and business activities.

Business model innovations as a result of business model management can be broad or focused. Based on Wilson's (1975) and Carroll's (1979) distinction between defensive, accommodative and proactive strategies and similar to Mitchell and Coles' (2003) business model innovation hierarchy a *basic typology of sustainability-oriented business model innovation* was developed (see Section 6): defensive strategic management to protect the current business model; accommodative strategic management to experiment within the given business model; and proactive strategic management leading to business model redesign in the focused sense. These strategies address the business case drivers with different intensities and focus, and thus differ in how likely and systematically a business model for sustainability will be achieved, with accommodation and pro-action being the most focused and promising.

However, despite the promises of business model innovations being the next big step of strategic management (e.g., Voelpel et al., 2004; Johnson, 2010), it has to be recognised that this kind of innovation often faces significant barriers. Chesbrough (2010) reviews central hurdles identified from previous academic research: conflicts with the current business model, conflicts with the underlying asset configuration, and missing clarity about the 'right' model to exploit an innovation (ibid, pp.358–359). *Conflicts with the prevailing model* can origin in two major sources: firstly, the resistance of managers being afraid that the acknowledgement of their personal contribution to the company might decrease if the modus operandi changes, and secondly, the influence of the dominant business logic on the information that flows into and circulates within the company. These inherent conflicts can result in strong resistance since managers prefer to do what they have always done and with what they have been successful (given the existing incentives) (e.g., Chesbrough, 2010; Prahalad and Bettis, 1995) and since organisations tend to learn what they already know (e.g., Argyris, 1999; Kim, 1993; Levitt and March, 1988). As a consequence *the current underlying asset configuration of the business model* may not be changed. Asset allocation and exploitation are key strategic issues directly related to managers decision-making and information availability. Accommodative and proactive business model innovations might be blocked because of allocation principles in favour of existing technologies with high gross margins: "As the firm allocates its capital to the most profitable uses, the established technology will be disproportionately favored and the disruptive [i.e., the new] technology starved of resources" [Chesbrough, (2010), p.358]. This can ultimately lead to decoupling (Meyer and Rowan, 1977) between the formulated strategies and actual behaviour.

Furthermore, *missing clarity about the 'right' business model* to exploit innovations may be another crucial obstacle for sustainability-oriented business model innovation. This failure is closely related to the influence that the dominant logic exerts on organisational learning and information availability. In their exemplary article on business model innovation at Xerox, Chesbrough and Rosenbloom (2002) were able to track back missed business opportunities to the underlying, dominant business model which created a lock-in effect against technologies which could not be exploited with the existing business model. Such an example was the very successful Ethernet protocol developed by 3Com, a company that commercialised a technology that did not match the Xerox business model. Chesbrough's (2010, pp.359–362) conclusion is that creating and adopting new business models by means of experimentation, effectuation and organisational leadership can help to overcome these hurdles.

Sustainability-oriented innovations are obviously predisposed to not fit with the dominant logic of an established business model. However, accommodative and proactive sustainability strategies may help creating and adopting new business models which support the continuous and systematic creation of business cases for sustainability.

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C. … and the case of solar energy

IV. Lüdeke-Freund, F. (2013, forthcoming): BP's solar business model: A case study on BP's solar business case and its drivers, Int. Journal of Business Environment.

BP's solar business model: a case study on BP's solar business case and its drivers

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Abstract: British Petroleum (BP) was among the first major oil companies to commercialise solar power technologies and was also one of the largest fully integrated photovoltaics companies. Following the oil crises of the 1970s and as part of its diversification strategy, BP built up its subsidiary BP Solar, which later became a central element in BP's corporate social responsibility and sustainability activities. But in 2011, BP Solar was shut down. However, before this the company did indeed have a 'solar business case' and this paper shows how this business case was realised and how BP tried to keep it going. Sources used were BP's annual reports from 1998 to 2011, which were studied by means of software-supported text analysis. For the reconstruction of the strategic drivers and business model innovations behind BP's solar business, a framework from sustainability management research was employed. It was found that an accommodative solar strategy was applied by the company and implemented through two business model innovation paths, the optimisation of module manufacturing combined with completely new distribution models.

Keywords: British Petroleum; BP Solar; solar energy; business case for sustainability; business case drivers; management; business model; strategy; innovation; business environment; case study; content analysis.

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1 Introduction

A fundamental question raised in the debate on the future of the energy system is how large energy producers and users can become 'green' and adopt renewable energies (Gliedt et al., 2010; Jacobsson and Johnson, 2000; Verbong and Geels, 2007; Wüstenhagen et al., 2007). Power from wind, water and solar radiation is gradually being integrated into the portfolios of electric utilities. But while these are just starting to deal with renewables (Richter, 2012; Wüstenhagen and Bilharz, 2006), a few major oil companies have been active in photovoltaics, i.e., the direct conversion of solar radiation into electricity, on a global scale and for more than three decades (Pinkse and van den Buuse, 2012).

It is often overlooked that the oil giants have been important agents for the diffusion and upscaling of wind and solar power (e.g., Backer, 2009; Backer and Clark, 2008); Pinkse and van den Buuse (2012) provide an insightful study of the solar activities of British Petroleum (BP), Shell and Total. Motivated by the 1970s oil crises and increasing public concerns about climate change, BP especially introduced its solar business as a contribution to a sustainable energy future (Browne, 2000). Its subsidiary BP Solar, founded around 1980 and closed in 2011, was among the commercial pioneers of solar power and one of the largest vertically integrated photovoltaics companies with a world market share at one time of 20% (BP, 2003c). However, this engagement was accompanied by public distrust and accusations of greenwashing (Beder, 2002; Greenpeace, 2010; Lüdeke-Freund and Zvezdov, 2013). An earlier case study of BP identified a sustainability risk-avoiding strategy, i.e., an approach to protect the company's licence to operate, for example through its solar activities, while at the same time avoiding financial trade-offs caused by sustainability issues (Perceval, 2003).

Large energy companies have a unique responsibility due to their key role within the global energy system and society (cf. Frynas, 2005, 2009). Making them into genuine supporters of renewable energies depends on the availability of technological solutions – but it hinges just as much on business solutions and profits (Jacobsson and Lauber, 2006; Menanteau et al., 2003; Schaltegger and Wagner, 2011). However, too narrowly defined business cases might hinder the permanent 'greening' of companies – they have to affect the core business and must be maintained in times of upheaval. In some cases, temporary losses are inevitable, as is illustrated by BP Solar.

On the occasion of its recent closure this paper provides an in-depth case study of BP Solar. A qualitative content analysis of BP's annual and sustainability reports from 1998 to 2011 gives a systematic picture of how the company developed its solar business. The research question is: how did BP develop the strategic drivers and business model of its solar activities and how did the company realise a 'solar business case'? This paper will show that BP realised its economic solar business case in 2004 and went on to follow an ambitious expansion path. The company was under pressure to develop a portfolio of large-scale projects to make full use of its manufacturing capacities and compensate for falling module prices. However, BP Solar did not meet the group management's expectations. This justifies the assumption that non-financial effects like improved reputation or innovative capabilities did no longer justify its existence and led to a strategy turnaround. To understand BP's solar business case and BP Solar's closure better, this paper offers a reconstruction of its underlying strategic drivers and business model.

The paper proceeds as follows: its analytical framework is introduced in Section 2. Section 3 describes the case study method, the text archive compiled and the analytical process used. BP Solar is introduced in Section 4 while Section 5 reconstructs its business case drivers and business model. Section 6 discusses the major findings from the content analysis and shows that BP applied an accommodative strategy to develop its solar operations. Moreover, two business model innovation paths are identified, the 'optimisation path' and the 'new markets path'. Conclusions are presented in Section 7.

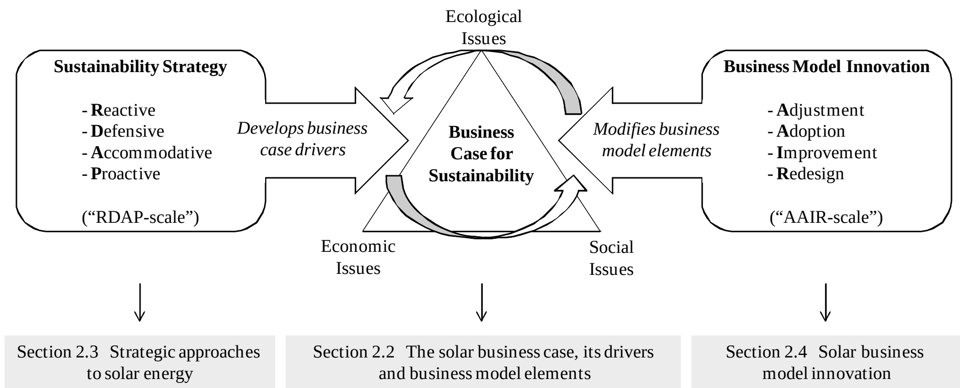
2 Analytical framework

2.1 The 'business case for sustainability' framework

The analytical framework of this study is grounded in the 'business case for sustainability' concept (Schaltegger and Wagner, 2006). In essence, business cases for sustainability are based on the creation and management of positive interrelations between business success and contributions to a sustainable development of the economy and society (e.g., Epstein and Roy, 2003; Dyllick and Hockerts, 2002; Salzmann et al., 2005). On this view, business cases go beyond legal compliance and result from distinct, mainly voluntary activities. Schaltegger et al. (2012) extend this concept and propose a framework with an emphasis on the interrelations between sustainability strategy and business model innovation (Figure 1). They suggest that to create, manage or analyse business cases the interplay between sustainability strategies and business model innovations needs to be understood. It is this rationale that is applied to BP's solar business in this paper.

Business case drivers, i.e., enablers or inhibitors of business success, such as costs, risks or sales, have to be strategically developed and managed (left-hand side of Figure 1). At some point, they reach their maximum positive effect on business and sustainability performance within a given business model and trade-offs occur that reduce either a company's economic, environmental and/or social effectiveness (Hahn et al., 2010; Schaltegger and Burritt, 2005). *Business model innovation* is seen as a means to provide additional leverage to business case drivers by overcoming the limitations of a given business model (right-hand side of Figure 1) (Boons and Lüdeke-Freund, 2013; Hansen et al., 2009). The interplay of drivers, business model innovations and their effect on business cases for sustainability is indicated by their circular interrelation in Figure 1.

Figure 1 Extended business case for sustainability framework



Source: Based on Schaltegger et al. (2012)

This framework is used for two reasons. First, BP's solar engagement had all attributes of a business case for sustainability as it was built on a voluntary basis, had positive social, environmental and business effects (at least temporarily), and was based on distinct decisions and activities, i.e., it did not happen accidentally (Schaltegger and

Lüdeke-Freund, 2013). Second, the framework defines the interrelations between different analytical concepts which help to understand the case in focus.

2.2 The solar business case, its drivers and business model elements

The triangle in Figure 1 represents the concept of the business case for sustainability with its emphasis on the integration of social, ecological and economic issues. Integration means that multiple goals are addressed simultaneously, in particular those of business success and contributions to the solution of social and/or environmental problems (Epstein and Roy, 2003; Schaltegger and Burritt, 2005). The present case study is about photovoltaics, i.e., an energy technology that reduces greenhouse gas emissions, mitigates energy dependence, provides employment and, under certain conditions, stimulates social progress (Schillebeeckx, 2012; Tsoutsos et al., 2005; Zahnd and Kimber, 2009). Hence, companies that develop and deploy photovoltaics always produce positive external effects (mostly supported by favourable public policies and regulations). If the interrelations between business activities and social and/or environmental contributions are recognised and actively managed, companies can develop and strengthen different business case drivers and their direct and indirect effects on economic performance (cf. Bresciani and Oliveira, 2007). Major drivers frequently discussed in the literature are shown in Table 1.

Table 1 Major drivers for business cases for sustainability

Major business case drivers	*Potential business case effects of sustainability activities*
Costs and cost reduction	E.g., energy savings, reduced material flows, reduced compliance costs
Risk and risk reduction	E.g., reduced technical, political or societal risks, elimination of sources of risk
Sales and profit margin	E.g., increased sales through new products and services, new customers
Reputation and brand value	E.g., reputation for safe operations, social awareness, innovativeness
Attractiveness as employer	E.g., access to employees that would otherwise avoid the company
Innovative capabilities	E.g., the ability to develop and market new technologies or business models

Source: Schaltegger et al. (2012)

Following the framework's rationale, these drivers' business case potential depends on the underlying strategic posture (left-hand side in Figure 1), but it also depends on the business model and its innovation (right-hand side in Figure 1). The concept of Osterwalder and Pigneur (2010) is used to reconstruct BP's solar business model. It combines four basic elements (Table 2). Any business model focuses on the *value proposition* for its customers. Therefore, the *business infrastructure* combines own and third-party activities and resources to develop competitive value propositions, i.e., products and services. To offer these to target customer segments the *customer interface* establishes communication and distribution channels as well as customer relationships. Finally, the *financial model* optimises the costs incurred by the business infrastructure and the revenues obtained from the customer interface to appropriate economic value for the company.

Table 2 Major business model elements

Major business model elements	*Short description*
Value proposition	Products and services offered
Customer interface	Target customers and channels and relationships to reach them
Business infrastructure	Business partners, own and third-party activities and resources
Financial model	Costs of business infrastructure and revenues from customer interface

Source: Osterwalder and Pigneur (2010)

2.3 Strategic approaches to solar energy ('RDAP-scale')

Several studies use taxonomies to characterise environmental and sustainability strategies (e.g., Aragón-Correa and Rubio-López, 2007; Henriques and Sadorsky, 1999; Sharma, 2000). While some authors take a corporate social responsibility (CSR) or corporate sustainability perspective (e.g., Carroll and Shabana, 2010; Schaltegger and Wagner, 2011), others focus on business and natural environment interdependencies (e.g., Aragón-Correa and Sharma, 2003; Bresciani and Oliveira, 2007; Dahlmann and Brammer, 2011; Gliedt et al., 2010; Hart and Dowell, 2011). The strategy taxonomy in Figure 1 follows the widely accepted 'RDAP-scale' proposed by Henriques and Sadorsky (1999):

Reactive strategies are associated with cost-constrained behaviour and a tendency to non-compliance with environmental or sustainability standards. A reactive strategy neglects the opportunities of solar energy. *Defensive strategies* are regulatory-driven and sensitive only to pressing issues. A defensive company engages in solar energy because of regulatory pressure. *Accommodative strategies* are based on a more open and active posture as top managers and employees are concerned to some degree with environmental and sustainability issues. Production processes and products may be changed, but the core business model is not affected. In this case, solar energy would be seen as an additional business opportunity. *Proactive strategies* result in greater changes that are supported by top managers and specially trained staff. Proactive firms deploy sustainability management and reporting systems which significantly shape the core business and might also lead to radical business model transformations, such as the provision of solar energy services instead of power produced from coal.

2.4 Solar business model innovation ('AAIR-scale')

Business model innovations for solar power gain increasing attention in current research (Buitenhuis and Pearce, 2012; Loock, 2012; Richter, 2013; Schoettl and Lehmann-Ortega, 2011), which is based on the assumption that the diffusion of solar power also depends on the way it is brought to the market, i.e., how well it meets customer expectations and competes with conventional technologies (Wüstenhagen and Boehnke, 2008). The different intensities of business model innovation considered in the framework's 'AAIR-scale' have different effects on a business model's composition. It can be assumed that more radical solar strategies lead to more radical business model innovations. Four intensities are distinguished (see also Boons and Lüdeke-Freund, 2013; Mitchell and Coles, 2003):

Adjustments change a minor number of elements while the value proposition remains the same. These are incremental and separate modifications of the business infrastructure, the customer interface or the financial model. *Adoptions* lead to new value propositions, e.g., to meet new demand or copy competitors' offers, without changing the basic business model. *Improvements* are changes of a major number of elements. Like adjustments, these have no effect on the value proposition, but since improvements affect many elements simultaneously they are of a more systemic nature. *Re-designs* occur when improvements (or accumulated adjustments and adoptions) lead to completely new value propositions and redefine the underlying business logic (e.g., from energy supplier to climate change advisor). Re-designs can lead to the abolition of a once established model.

This framework and its concepts – i.e., business case, strategic approaches and business model innovation – will structure the present analysis of BP's solar business. The six business case drivers serve as the main coding categories in the content analysis of BP's major drivers and the underlying strategic approach, while the four business model elements will be used to reconstruct BP's solar business model and related innovations.

3 Case study methodology

3.1 BP Solar as a single case study

The research question addresses real-life events which can be analysed ex post without being influenced by the researcher. Therefore, a case study was the method of choice (Yin, 2009). The decision for a single case design was based on the expectation that BP Solar was an extreme or deviant case, to use Flyvbjerg's (2011) term. The extreme aspects are, inter alia, the fact that an oil major was active in photovoltaics for more than 30 years; that BP Solar was successful and well respected for its products; and that the company left the field when large-scale production and application were bringing long-awaited economies of scale. These case characteristics also seemed to be appropriate to test the analytical strength of the framework. The main aim, however, was to answer the research question by showing how particular solar business case drivers and business model innovations were developed over time.

For this purpose, a software-supported text analysis and content coding were conducted of BP's annual and sustainability reports as well as further corporate publications. BP Solar could not be considered separately from its parent company since no special solar reports were published. Therefore, an embedded study design was developed (Yin, 2009): BP Solar (unit of analysis) was studied as a part of BP (case) against the background of the solar industry (context). The analysis was based on the assumption that BP's reporting portrayed the company's solar activities in a more or less systematic way. It was assumed that BP tried to show the soundness of its solar investments (for critical shareholders) and that these were more than greenwashing (for other critical stakeholders), thus providing the necessary data for a detailed analysis (cf. Abbott and Monsen, 1979; Duriau et al., 2007).

The major limitation of this method was the external perspective and the potentially biased documents due to information asymmetries between sender and recipient (Bowen, 2009; McWilliams et al., 2006). This limitation was paid special attention in the present study. For example, BP reported extensively on its social solar projects in the Philippines and gave the impression that its solar business was based on a social mission; but these projects were part of BP's CSR strategy. Their extensive communication was therefore interpreted as an exercise in reputation management rather than a representative feature of BP's solar business. This does not mean, however, that annual reports have no role to play in organisation studies. They are, in fact, widely accepted (Duriau et al., 2007) and Abbott and Monsen (1979), for example, have shown that reports can be used to analyse sensitive issues like CSR measurement.

3.2 Data collection and analysis

Four steps were taken to uncover the information looked for: *data collection*, *document selection*, *content coding*, and *reconstruction*.

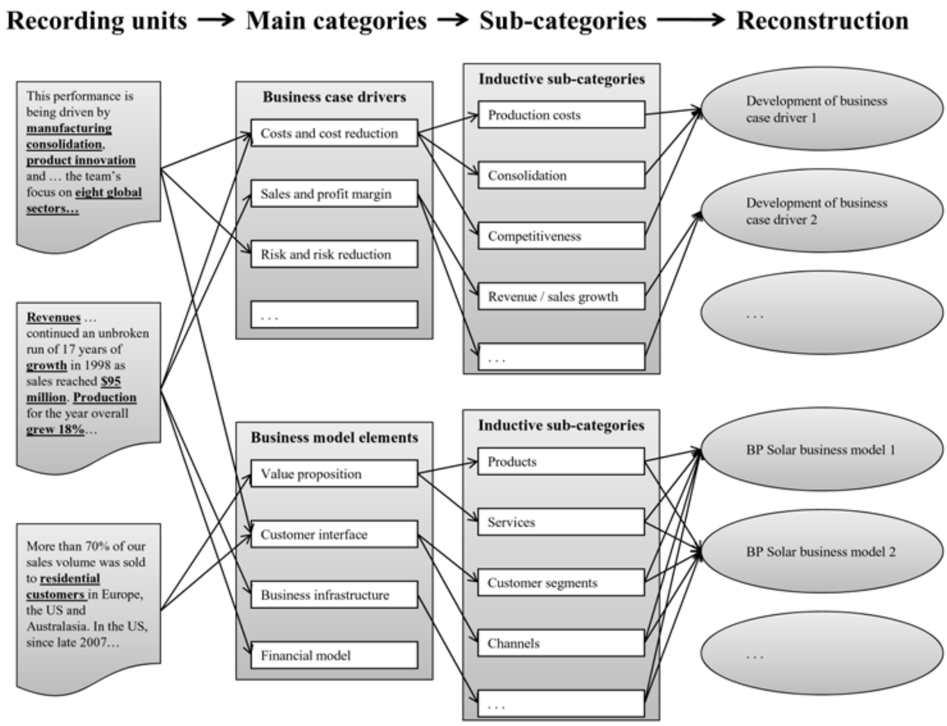
- *Data collection:* BP's website was used as database. It offers different search options and access also to earlier releases. Three search strings were used ('solar', 'BP Solar' and 'Solarex'), leading to 387 relevant documents. 'Solarex' was used because BP Solar was renamed BP Solarex for a short time after the BP Amoco merger. Additional information on BP Solar's business model was collected from a web archive.[1] The timeframe 1998 to 2011 was determined by the availability of annual reports.
- *Document selection:* The annual and sustainability reports were used as primary sources (28 files, 1,854 pages), while speeches (177 files, 1,114 pages) and press releases (182 files, 391 pages) served as backup for additional details.
- *Content coding:* All documents were imported into the text analysis software MAXQDA. A keyword search for 'solar' and 'photovoltaic' brought 455 results. The respective sentences and paragraphs served as recording units. In a first coding round, these were coded against the main categories from the analytical framework (Table 3). In particular, it was decided whether the passages contained information on business case drivers or business model elements. In further rounds, the coding was refined through emerging inductive subcategories which led to a combination of deductive and inductive coding (Elo and Kyngäs, 2008; Fereday and Muir-Cochrane, 2006).
- *Reconstruction:* The main task was to reconstruct the development of the solar business case drivers and business model innovations. This reconstruction required more than summarising scattered text fragments as the reports did not describe 'drivers' and 'business model innovations' per se. Moreover, each publication took a different approach to reporting on solar activities. Thus, the reconstruction task was to make sense of bits and pieces (Elo and Kyngäs, 2008). The reconstruction process is illustrated in Figure 2.

Before the business case drivers and business model innovations are presented in Section 5, BP Solar is introduced in more detail.

Table 3 Coding frame for business case drivers and business model elements

Deductive main categories	*Inductive sub-categories based on analysed reports (examples)*
	Business case drivers
Costs and cost reduction	Production costs, consolidation, competitiveness
Risk and risk reduction	Climate change, risk management
Sales and profit margin	Revenue/sales growth, production capacity, market development
Reputation and brand value	Industry leadership, technological leadership, social projects
Attractiveness as employer	Human resource management, employee satisfaction
Innovative capabilities	Innovations, products/processes, efficiency
	Business model elements
Value proposition	Products: modules, total systems; services: installation, project development
Customer interface	Customers: homeowners, utilities; channels/relations: direct and online sale
Business infrastructure	Partners: trained installers; resources/capabilities: manufacturing, installation
Financial model	Costs: total system costs; revenues: system price, grants, feed-in tariffs

Figure 2 Content coding and re-construction process



4 BP Solar – a former solar market leader

4.1 An integrated solar company

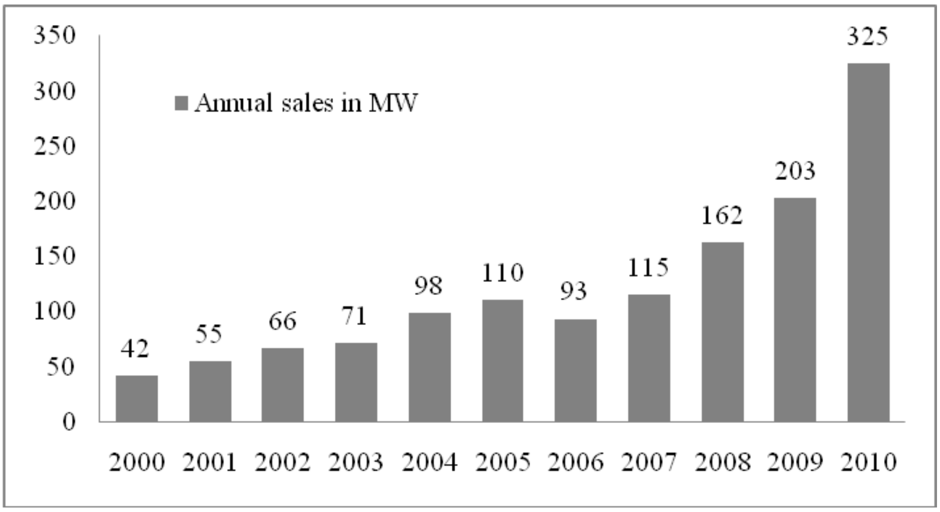
BP Solar's operations were based on an integrated value chain including silicon, cell and module production and the design and installation of total systems. Before it was restructured (see Section 4.2), the company had 2,200 staff and owned manufacturing facilities in Australia, China, India, Spain, and the USA. Until 2011, 1,600 megawatt (MW) of solar products were sold to 160 countries.

Regarding major features of BP Solar's business model, the reports highlight *products and services* like building-integrated photovoltaics, pre-packaged residential systems and project development for utility-scale investors. The original core business was module production and distribution through a global network of wholesalers and certified installers.

The *customer interface* addressed different target markets ranging from small-scale residential installations to solar parks for electric utilities and financial investors. BP Solar was among the first to target private customers in mass marketing campaigns in the USA (BP, 2003a). As of 2008, this segment accounted for 70% of all sales (BP, 2009a). Later, when the business model changed from module production to project development, commercial customers and investors were the primary target groups (Parkinson, 2011; Riddell, 2009). The USA (California) and Europe (Germany and Spain) were the most important markets due to favourable public solar policies.

The *business infrastructure* was focused on the production of crystalline modules. Between 2008 and 2011, all exclusively owned factories were replaced by strategic partnerships to reduce costs. Also, BP Solar's business infrastructure was permanently adapted to the changing business environment. For example, the global silicon shortage from 2005 to 2006 (Jäger-Waldau, 2006) was answered with new production processes and long-term contracts with major suppliers (Hering, 2009).

Figure 3 BP Solar's annual sales 2000–2010 in MW



Source: BP, annual reporting

The reports do not reveal details about the *financial model*. Cost figures are not reported and revenues are published irregularly (1998: $153 m, 1999: $179 m, 2003: $307 m, 2004: $410 m, 2005: $500 m). However, BP Solar's growth is well documented in terms of MW sales (Figure 3). It follows from Vanden Plas (2008) that the official goal of an annual revenue of one billion dollars (BP, 1999b) was achieved in 2007.

4.2 From business case to business closure

As a central element of BP's 'beyond petroleum' rebranding (2000) and the BP Alternative Energy unit (founded in 2005), the solar business was important for the group's reputation as a modern and green energy company (Beder, 2002; Browne, 2000; Lüdeke-Freund and Zvezdov, 2013). At the same time, expectations were emerging both within the group and in the public at large that BP would create a substantial business (BP, 2001b). BP's top management was aware of this challenge:

> "… four years ago we took a hard look at our solar business because it had never been profitable. We faced up to the fact that it needed to become profitable in order to grow. Without profitability BP Solar would never be treated on an equal basis with other businesses in BP … It would remain as a non-core activity and would be derided externally as 'greenwash'. It had to be a real business." (BP, 2006b)

This 'hard look' led to the first restructuring programme (2002–2003), in the course of which BP Solar made its first-ever operating profit in 2004, making it the year of BP's economic solar business case. "Solving the solar equation" [BP, (2005a), p.21] was reached through different measures, including the reduction of product lines, the closure of thin film manufacturing, and the introduction of new retail and project business models. In 2009, the second restructuring programme was launched to cope with an increasingly difficult business environment. The solar market was hit by the financial crisis (Lüdeke-Freund and Loock, 2011) and changing policy regimes (Avril et al., 2012), while new module producers, fierce cost competition and overcapacities were exerting additional pressure (Jäger-Waldau, 2009). Based on an interview with Reyad Fezzani, BP Solar CEO from 2008 to 2010, the *San Francisco Business Times* wrote:

> "The company was at one time the second-largest manufacturer of solar panels in the world ... but its market share has eroded in the past several years as BP struggled to compete with cheaper Asian manufacturers. Today, BP doesn't make the Top 10 list for panel manufacturers." (Riddell, 2009)

Two years later, BP Solar was closed because the industry had become a 'low-margin commodity market' [BP, (2012b), p.3]. However, in previous years, BP had strong growth in sales (profits were not reported) and was one of the world's leading module suppliers (Jäger-Waldau, 2007), i.e., the company knew how to 'solve the solar equation'. Moreover, it can be assumed that its solar business case was not only about financial profits on the business unit level, but that multiple business cases must have existed on the group level – e.g., in terms of reputational gains and access to new energy markets. This is borne out by the literature on strategic environmental and sustainability management, where various kinds of motivations beyond direct financial effects are discussed (Section 2.2) (cf. Bresciani and Oliveira, 2007; Epstein and Roy, 2003). For a deeper understanding of BP's solar business case, the next section reconstructs its major drivers and business model innovations.

5 BP's solar business case drivers and business model innovations

5.1 Solar business case drivers

This reconstruction starts with the six major business case drivers introduced above (Table 3). Their compilation illuminates the challenges which had to be solved through business model innovation (for example, cost reductions, sales growth and improved customer focus). At the same time, this reconstruction offers a unique perspective on BP Solar's development in the recent past.

5.1.1 Costs and cost reduction

An issue in nearly every report is improvements in module production processes. High cost pressure is typical of the solar industry, leading to low-cost strategies and the relocation of production to Asian countries, especially China (Grau et al., 2012). Low manufacturing costs are critical for low electricity costs and mass market acceptance:

> "Our strategy is to invest in lower-cost manufacturing to enable energy from our products to compete with conventional sources of electricity." [BP, (2009a), p.28].

In 2002, thin-film technologies were dropped in favour of cost competitive crystalline modules (BP, 2003a). Major productivity improvements were achieved in the subsequent 'lean manufacturing initiative' (BP, 2005a). Cost reductions were also sought by focusing on a small number of manufacturing sites and joint ventures with Indian (Tata BP) and Chinese (BP Sun Oasis) companies, as well as partnerships with third-party manufacturers (e.g., JA Solar and Hareon Solar) (BP, 2011a). In 2008 and 2009, the production facilities in Australia, the USA and Spain were closed, leaving India and China as sole manufacturing bases, and BP Solar's staff was reduced by 620 employees, i.e., by nearly 30% (BP, 2011a). Together these measures were expected to lower module costs by 25% (Hering, 2009).

Another aim was to increase module efficiency, for example, through the 'laser grooved buried grid' (LGBG) and 'Mono^2' technologies (Mason et al., 2002; Cunningham et al., 2008; BP, 2007a). Faced with increasing price competition, the challenge was both to offer modules with improved conversion efficiency *and* reduce production costs. BP Solar suffered, however, from two competitive disadvantages, manufacturing facilities in high-cost economies and sunk costs of decades-long technology development.

5.1.2 Risks and risk reduction

Improvements in safety and risk management were a top priority after the Texas refinery accident, the Alaska oil spills and the Deepwater Horizon catastrophe (BP, 2006a, 2007a, 2011b). Consequently, safety-related communication makes up a large part of BP's reports, as shown by a word count: 'risk' (n = 2,113) and 'safety' (n = 2,004) are mentioned as often as 'value' (n = 2,070), a permanent key term of annual reporting. BP's solar activities were related to a particular source of risk – climate change:

> "Climate change remains a major concern in the energy industry and beyond … We plan to continue advocating for action to reduce GHG emissions as well as providing low-carbon energy. In 2008, we plan to invest $1.5 billion in

> alternative and renewable energy technologies … and we plan to grow our solar sales to 800 MW in the coming years.” [BP, (2008b), pp.26–27]

This link between reducing the risks of climate change and renewable energies had been crucial in justifying solar power as a business for the oil major (cf. Browne, 2000; BP, 2007b).

5.1.3 Sales and profit margin

Different milestones were identified in terms of sales growth. BP Solar’s world market share was 18% after the Solarex merger in 1999 (BP, 2002) and annual growth rates reached 20 to 30%. In 2007, around 5% of the globally added photovoltaic capacity came from BP (BP, 2009b) and revenues reached one billion dollars. In 2009, when BP Solar celebrated its 10-millionth module (BP, 2010), the company was still close to the top ten producers. But competitors like Suntech (1,572 MW) realised gigawatt sales in 2010 and BP Solar (325 MW) was no longer able to stand the pace.

Translating the absolute sales figures (Figure 3) into annual growth rates illustrates the challenge of managing this business case driver. While, for example, sales grew by 38% in 2004, they declined by 15% in 2006 though growing again by 41% in 2008. Profit figures were not reported, but BP Solar was clearly struggling to provide stable and predictable results.

5.1.4 Reputation and brand value

The content analysis showed that reputational effects were the most important driver but also the most complex and hard to manage one:

> “We all know the appeal of solar power – sustainability, acceptability and independence. Yet its potential as an energy source has often been overshadowed by its economics as a business.” [BP, (2005a), p.21]

In line with the group’s ‘beyond petroleum’ rebranding, the appeal of solar power should have supported BP’s reputation as a modern energy company, but this attempt met with public scepticism (Beder, 2002; Lüdeke-Freund and Zvezdov, 2013). In response, the solar unit tried to strengthen its reputation as an industry leader.

The company’s market leader status is emphasised in most reports and underscored with large market shares, strong growth, superior products and decades of industry experience. BP Solar was to be perceived as a technology leader, for example, through showcases at the G8-summit and the Olympic Games, or the ‘SolarSail’ installed at the Guangdong Science Centre in China (BP, 1999a, 2009a). ‘The world’s biggest…’ was a phrase commonly employed, for example, to present social projects in the Philippines (BP, 2003a) or milestone installations in Germany (BP, 2005b). So called ‘Chairmen’s Prizes’ for technological achievements and social solar projects were a demonstration of the board’s awareness (BP, 2001a, 2004). Finally, BP Solar’s restructuring included measures to improve customer focus and brand loyalty through a clearer product portfolio and a tightened distribution network (BP, 2005a).

5.1.5 Attractiveness as employer

Different human resource management indicators are published in BP’s annual and sustainability reports [for instance, diversity, inclusion, safety, or satisfaction indices (cf. BP, 2012a)]. BP commits itself to supporting individual careers and the permanent improvement of policies and governance mechanisms of employee management. Regarding the solar business, however, only one statement was found:

> "Our real edge comes from *our people's ability* to be the best – in building customer relationships, in trading or in getting renewable energy to market. Solar and wind power both have enormous potential. Our challenge is to find the right balance between traditional and renewable sources as we move forward." [BP, (2002), p.8; emphasis added]

BP's employees are praised and directly linked to the challenge of developing renewable energies and balancing these with conventional energy sources.

5.1.6 Innovative capabilities

BP's innovation activities addressed the whole value chain from raw materials (silicon) to manufacturing (cells, modules) and total system design (e.g., solar parks) for different uses (e.g., remote or grid-tied systems). Most innovations aimed at cost reductions and improved module efficiency:

> "We aim to be a leader in the drive to reduce the costs of providing solar energy to levels at which it can compete strongly with oil, gas, coal and nuclear in the generation of electricity … This requires continued innovation and technology gains, including lower-cost panels, higher-efficiency cells and more productive 'total system' installations." [BP, (2006a), p.43]

The necessary innovative capabilities were originally based on technology buy-ins and joint ventures like Lucas BP Solar Systems (1981) or BP Solarex (1999). Lucas (UK) had explored the feasibility of marketing photovoltaics since the early 1970s and held the two largest solar energy contracts worldwide for the supply of telephone networks in Colombia and Algeria (Jéquier and Blanc, 1984). Later, BP Solar entered a joint venture with Solarex (USA) (BP, 1999a), which contributed its thin-film business and an impressive innovation track record: it had, for instance, introduced the multi-crystalline process in the 1970s, a new cell format in the 1980s, a new kind of amorphous silicon module and the industry's first warranties in the 1990s.

These externally acquired capabilities were combined with internal and joint R&D, e.g., with the California Institute of Technology (Caltech). BP's high-efficiency 'LGBG' cells were based on an invention made by researchers from the University of New South Wales, Australia (Wenham et al., 1994). After some in-house R&D, these cells were used in the 'Saturn' modules which became BP Solar's most successful products (BP, 2006a).

5.2 Solar business model innovations

While predefined categories were used to identify the business case drivers, the reconstruction of BP Solar's business model followed a slightly different approach since the specific model could not be defined in advance (Figure 2). The analysis revealed that BP's solar business model was in fact a portfolio of four market segment-specific models: *residential retrofit*, *homebuilder model*, *commercial customer models*, and *utility and investor model* (summarised in Table 4). The backbone of this portfolio was the production and distribution business model described in Section 4.

Table 4 Overview of BP's solar business models and their basic elements

Business model / *Elements*	*Residential retrofit model*	*Homebuilder model*	*Commercial customer models*	*Utility and investor model*
Value proposition	Simplified purchasing of standardised solar power installation packages allowed homeowners to retrofit their homes and produce green electricity. The packages were combined with consulting, planning, installation and financing services.	End-users benefitted from 'invisible' purchase and installation processes embedded into home-building projects. The installations were optimised for the respective home type and energy needs.	Different ownership and service models recognised customers' financial needs. Self-made green electricity was available without upfront investments. Calculable payments and all-in service arrangements provided a high degree of convenience.	Investors were offered green investment opportunities and benefits like tax credits, while utilities were interested in grid services provided by solar parks and options to fulfil their renewable energy obligations.
Customer interface	These products and services were provided through direct sales channels, including The Home Depot (THD), the world's largest home improvement retailer. THD offered BP's products online and in stores across the USA.	The systems were delivered through the channels of roofing companies and homebuilders who also raised customers' awareness for solar power. BPS representatives and installers provided pre and post sale services.	Extensive consulting and customisation were necessary to adapt the installation to customers' energy needs, buildings or industrial sites. Service contracts, warranties and BP's reputation guaranteed for reliable long-term operations.	Investors and utilities were both customers and business partners. Multilateral cooperation and specialised project companies were set up to structure these customer-partner relationships.
Business infrastructure	THD and certified BPS* representatives and installers were the most important partners. They carried out the necessary tasks and provided complementary resources.	Seamless components for different roofs and aesthetic preferences had to be developed (e.g., BP's 'EnergyTiles'). The multitier distribution network involved homebuilders, community planners, BPS representatives and installers.	BPS combined financing sources to which their customers had no access to set up PPA and lease models. Incentives like tax credits were monetised for the financiers. EPC and O&M were the main activities; these were partly outsourced.	Central were the development and financing of large projects which required hundreds of million dollars. A network of direct and indirect partners which included financiers, utilities, grid operators and regulators had to be managed.
Financial model	This approach resulted in costs for the total system and third-party services. Financing came from end customers, grants and tax credits from public authorities.	The cost-revenue structure was comparable to residential retrofit, but it can be assumed that it was more cost intensive due to additional design and engineering tasks.	The PPA and lease models combined three complementary perspectives 1 electricity users avoided upfront investments 2 external investors realised gains from tax credits and interest payments 3 BPS got paid for EPC and O&M services.	The financial model varied with the involved financiers and available revenue sources (e.g., PPAs, feed-in tariffs, tax credits, RECs). Costs included, e.g., EPC, O&M, land acquisition, capital (for pre and intermediate financing) and legal costs.

Note: *BPS = BP Solar.

5.2.1 Residential retrofit model

'BP Solar Home Solutions', the first branded photovoltaics offer for private homeowners in the USA, was based on a retail business model innovation that reduced the complexity of purchasing and installing residential solar systems (BP, 2003b, 2006a). This model, in which the world's largest home improvement retailer The Home Depot (THD) served as 'market maker' for solar packages and services (cf. Schoettl and Lehmann-Ortega, 2011; Schweizer, 2005), strengthened BP Solar's position in the USA. A completely new market was created and this business model innovation was copied and refined by new entrants like Grape Solar.

5.2.2 Homebuilder model

In cooperation with Northern California's largest roofing company, Old Country Roofing (OCR), solar systems were offered to homebuilders and developers of 'solar homes' and 'solar communities' which were eligible for public financial support (BP, 2006c). For example, the installation of BP's 2 kW system was supported with a $ 2,000 tax credit and a buy-down of $3 per watt capacity in the 'Fallen Leaf' community project (Porter and Vang, 2006). 'BP Solar Builder Solutions' were based on an innovative configuration of design, distribution and customer services. This model was new in that it combined roofing, homebuilding and community development with specially designed solar equipment and public financial support. BP Solar and OCR pioneered this market in California and became a role model for firms like PetersenDean, one of the largest roofing and solar contractors in the USA.

5.2.3 Commercial customer models

'BP Solar Business Solutions' were based on different financing and ownership models. Under the asset purchase model owners of commercial buildings or industrial sites bought the solar systems directly, while the service and lease models were forms of third-party ownership (Frantzis et al., 2008). Commercial installations are larger than residential systems and require extensive assistance during engineering, procurement and construction (EPC), and operation and maintenance (O&M) (Schoettl and Lehmann-Ortega, 2011). *Asset purchase* was comparable to residential retrofit in that turnkey systems were delivered to end-users who owned the installations. System owners were eligible for tax credits and incentives like renewable energy credits (RECs) but had to finance the system on their own. The capital requirements restrained many potential customers from using solar power (Frantzis et al., 2008). This barrier was removed by *service agreements* (Power Purchasing Agreement, PPA) and *lease arrangements*. BP Solar provided for third-party funding when commercial electricity users were unwilling or unable to finance an installation. Financing models were developed that combined capital from banks and equity investors who were repaid on the base of PPAs or lease contracts. Electricity users paid only a fixed rate per kWh (PPA) or per month (lease). Commercial customers of BP Solar were, e.g., the United States Marine (asset purchase, 1.3 MW), FedEx (PPA, 2.4 MW) and Walmart (PPA, 12.9 MW).

5.2.4 Utility and investor model

The fourth business model targeted the utility-scale segment in which projects in the two or three-digit MW range were developed for electric utilities and investors. This market had emerged only recently in the USA for which former CEO Fezzani estimated a market size of 1,000 MW in 2009 (Hering, 2009). In 2012, NREL found that approximately 16,000 MW of utility-scale projects (> 5 MW) were under way (Mendelsohn and Kreycik, 2012). BP approached this market in different roles (cf. Schoettl and Lehmann-Ortega, 2011), as module supplier (e.g., for the 45 MW solar park in Koethen, Germany) and project developer, i.e., EPC ‘orchestrator’ (e.g., for the 32 MW Long Island installation). Turning to this segment and its promise of a mass market for solar modules, BP continued to ramp up manufacturing capacities through joint ventures and third-party manufacturing.

6 Discussion

6.1 Strategic assessment of BP’s solar business case drivers

The business case framework suggests that sustainability initiatives, such as the introduction of renewable energy technologies, can follow *reactive*, *defensive*, *accommodative*, or *proactive strategies* (Section 2.3). In consequence, the development of business case drivers will follow one of these approaches. Based on the reconstruction of BP’s solar business case drivers the company’s strategic posture can be inferred (summarised in Table 5).

It follows from the business case concept that sustainability initiatives can improve a company’s *cost* situation. According to BP’s reporting, however, this was not the case for its solar activities, neither for module manufacturing nor power generation, both of which were always compared to the oil and gas businesses. Oil and gas were described as cost-efficient and profitable, whereas the solar industry had turned into a low-margin commodity market. This comparison and the emphasis on solar’s relatively higher costs were seen as an indicator of a rather *defensive* attitude. That is, BP Solar’s cost position and efforts to reduce manufacturing and power generation costs had no positive business case effect on the group level. The oil and gas benchmarks were out of reach.

The framework proposed by Schaltegger et al. (2012) also contains a second cost-related aspect beyond production costs – the internalisation of *external costs* for society and the natural environment (cf. Krewitt, 2002; Rafaj and Kypreos, 2007). BP mentions an internal CO_2 cost accounting system for investment appraisals and engineering designs (BP, 2010), but it remains unclear how this system influences decisions about energy projects and accounts for the different external costs incurred by fossil fuels and solar energy [BP’s auditor Ernst & Young criticises this lack of clarity (BP, 2012b)].

Table 5 Assessment of BP's solar business case drivers

Drivers	*Strategic attitude**				*Reasoning***
	R	*D*	*A*	*P*	
Costs and cost reduction		X	(X)		Solar technology and power always described as too expensive and non-competitive with fossil fuels or other low-carbon alternatives Pro accommodative: BP established a dedicated green power unit to realise operational synergies Contra accommodative: cost benchmarks of fossil fuel core business were dominating
Risk and risk reduction			X	(X)	Solar energy introduced as a part of risk management to answer to the 1970s oil crises and global warming Pro proactive: solar was added to BP's technology portfolio when it was still far away from a mass market Contra proactive: sources of risks, i.e., sources of CO_2-emissions were not reduced or removed
Sales and profit margin			X		Solar technology and power addressed green market segments, showing awareness of green technology and power markets besides the existing fossil fuel core business; permanent sales growth and attempts to make solar profitable
Reputation and brand value			X		BP had to balance positive reputation effects as green energy supplier and accusations of greenwashing; BP Solar had a market leading position, i.e., more than a defensive strategy, but at the same the BP group is not a proactive sustainability leader, leading to a fragile balance of reputation gains and losses
Attractiveness as employer			X	(X)	Solar business might have attracted people that otherwise would not have worked for BP Pro proactive: HR management with a focus on developing people; Browne's climate change speeches given at different top universities Contra proactive: sustainability not central to BP's reputation; might discourage potential employees; radical job cuts in the solar unit
Innovative capabilities		X	(X)		Solar innovations were neither questioning the group's business logic nor its overall innovation goals; cost efficiency was main motivation Pro accommodative: solar products integrated into product range and marketed under strong BP brand Contra accommodative: no radical breakthrough inventions, but cost-oriented optimisation as main innovation strategy

Notes: *R = reactive, D = defensive, A = accommodative, P = proactive
**Cf. Schaltegger et al. (2012, pp.102–105)

As for *risks* related to sustainability issues, such as climate change, the framework proposes various approaches, from ignorance (reactive) to an active elimination of risk sources (proactive). Climate change is a double-edged sword in BP's case. On the one hand, the company might lose its 'license to operate' as a supplier with permanently growing sales of CO_2-emitting products. On the other hand, facing this risk offers new business opportunities. The societal perception of climate change as a fundamental threat became a major driver for BP's solar business which might have supported BP's license to operate at the group level through the development of new renewable energy businesses (cf. Browne, 2000; BP, 2007b). These businesses were seen as a complementary and opportunity-creating business field, indicating a rather *accommodative* approach.

In line with BP's *accommodative* strategy, the company recognised customer segments interested in clean energy technologies and green power, created corresponding business fields and sold solar equipment and power in large quantities while the original core business remained unchanged. However, module and power *sales* were hardly drivers for a business case in the usual order of magnitude on the group level, as this quote from the 2004 annual report shows:

> "We're now running a profitable solar operation – still small by BP standards, but one that grew its megawatt capacity sales of photovoltaic equipment by more than 30% …" [BP, (2005a), p.21]

Despite continuously growing sales, it is safe to assume that one important business case driver lagged behind: *profits*. BP Solar realised its first ever profit in 2004, but seems to have struggled to sustain it. In 2009, for instance, the total production capacity was 320 MW (BP, 2009c), but actual capacity sales of 203 MW (BP, 2011a) indicate an unused capacity of around 35%. The facilities in Australia, Spain and the USA were closed and 620 solar jobs were cut in the same year. Two years later, the official reason for leaving the industry was low profit margins (BP, 2012b).

As BP has always been confronted with accusations of greenwashing (Lüdeke-Freund and Zvezdov, 2013), the solar business could not be guaranteed to enhance BP's standing in terms of *reputation*. BP Solar reached a market leading position, but its relative size within the group always undermined its credibility. However, the content coding brought up more than purely reputational and risk-oriented, i.e., defensive, activities. Being among the first global solar companies with a considerable track record in improving product performance and distribution outreach qualifies BP as an important contributor to the development of the global solar industry. The approach to developing this business case driver can be rated as *accommodative*. Nevertheless, recurring greenwashing allegations [e.g., Greenpeace's (2008) 'Emerald Paintbrush' award in 2008] reveal that BP's solar business had a limited or even negative effect on the group's reputation as an oil company that supports renewable energies.

The quote in Section 5.1 expresses the trust placed in *employees* that they will exploit the potential of solar energy. However, a direct report-based assessment of BP's strategy for attracting employees with and for the solar business was not possible. The solar business might presumably have attracted people who would otherwise not have worked for BP. The reporting on the group's employee management with its focus on developing people seems to point to a proactive attitude. So do John Browne's climate change speeches given at Stanford University which can be seen as an attempt to attract elite students with sustainability issues (cf. Browne, 2000; BP, 2007b). However, following

Schaltegger et al. (2012), a proactive strategy requires a high sustainability reputation to interest motivated people, but this must be questioned for BP. The development of this business case driver was therefore rated as rather *accommodative*.

Assessing the *innovation* driver according to the RDAP scale is challenging. BP’s capabilities enabled the company to become a market leader with high-efficiency crystalline modules. But with regard to alternative conversion technologies and application concepts, most innovation efforts were only focused on cost reductions. While various innovation activities are reported, even radical approaches like solar-nanotechnology, the dominating motivation identified is cost reduction, without a doubt an absolute necessity in the photovoltaics industry. However, according to the business case framework this driver was developed in a rather *defensive* manner showing some accommodative traits.

From this assessment can be concluded that BP pursued an accommodative strategy to develop its solar business.[2] Costs, sales (profits) and reputation can be seen as critical drivers for the development of a solar business case. While costs and sales had to be managed on the solar unit level to realise an economic business case, reputation effects were critical on the group level. BP had to offset a lack of ‘green’ credibility with reputational gains from its solar activities. A major approach to solving these intertwined problems was business model innovation (Section 6.2). BP tried to scale up its solar business to achieve multiple goals. Global outreach and large market shares were necessary to realise economies of scale and strengthen BP’s standing as a real photovoltaics company.

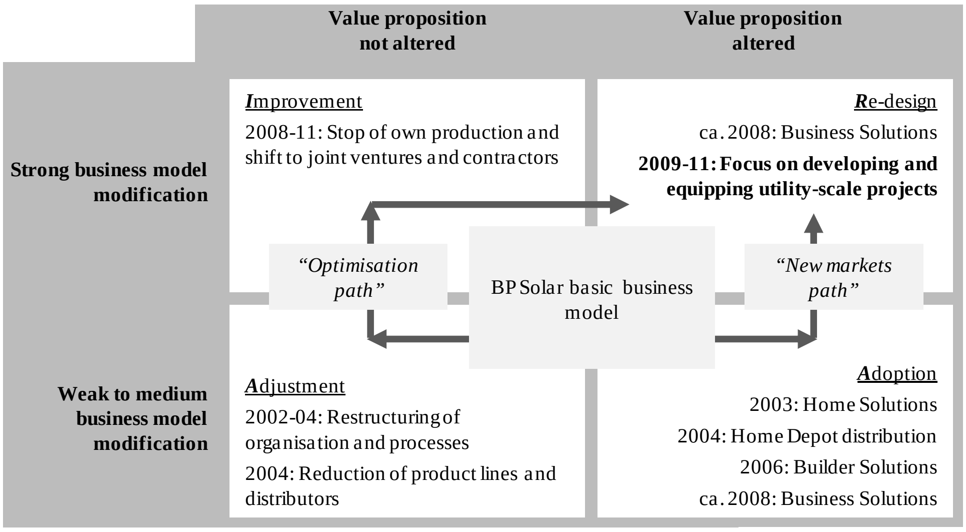
BP’s strategy was accommodative not only with regard to how the company dealt with solar energy as a sustainability issue, but also what concerned general strategic accommodations over time. The above discussion provides an aggregated and rather static picture, but strategies are likely to change over time because of altering business environments, emerging business opportunities and changing top management priorities (cf. Aragón-Correa and Sharma, 2003). Pinkse and van den Buuse (2012) analysed the chronological development of BP’s strategic motivation to engage in photovoltaics. The first milestone was BP’s response to the 1970s oil crises and decreasing industry growth. Solar energy was part of a broader diversification strategy to reduce market risks. In the late 1990s, John Browne, Group CEO from 1995 to 2007, promoted solar energy as BP’s response to climate change (Browne, 2000). This second milestone of strategy evolution connected BP’s solar business to CSR and sustainability considerations. Moreover, it played a major role in Browne’s ‘beyond petroleum’ rebranding and became the mainstay of BP Alternative Energy. The authors fail, however, to mention a third milestone, which might have been a turning point as it demonstrated a strategic backlash against BP Solar: the nomination of Tony Hayward as Group CEO (2007–2010) after Browne had to resign (Lüdeke-Freund and Zvezdov, 2013). The first annual report published under Hayward is clear about the fact that BP creates and always will create value for its shareholders by exploring and refining hydrocarbons (BP, 2008a). Two strategic objectives are defined for the solar business, suggesting an exclusive economic business case focus: tripling cell production capacity and reducing solar power costs.

6.2 BP’s Solar business model innovation paths

Using the business case framework, BP’s solar business model innovations can be rated against the ‘AAIR-scale’ as being *adopted*, *adjusted*, *improved*, or *re-designed*. Figure 4 shows the most important innovation moves, starting from BP Solar's basic business model, i.e., a vertically integrated photovoltaics manufacturer, at the centre of Figure 4. The matrix distinguishes between the strength of business model modifications, weak/medium or strong (vertical axis), and the question of whether these include novel value propositions (horizontal axis).

According to the definitions given above, *adoptions* and *adjustments* lead to weak or medium modifications, while *improvements* and *re-designs* yield more extreme ones (Section 2.4). However, only adoptions and re-designs include new value propositions. This heuristic is used to describe the paths of BP's solar business model innovations. Two major paths were identified.

Figure 4 BP's converging solar business model innovation paths



The first path (adjustment – improvement – re-design), the *optimisation path*, comprised two milestones related to the above mentioned restructuring efforts in pursuit of cost competitiveness, in the course of which the business organisation and production processes were restructured, product lines reduced, and the distribution network tightened (2002–2004). This *adjustment* changed individual business model elements like activities, resources and channels, but did not alter the value propositions. In a later phase, from 2008 to 2011, more far-reaching steps were taken. Exclusively owned production facilities were closed, and cell and module production was completely shifted to either joint ventures (e.g., Tata BP) or contractors (e.g., JA Solar) in India and China. Although a strong business model modification, this *improvement* did not alter the value propositions and impacted only on business infrastructure elements like partnerships, resources and activities. Above all, the aim was to develop a low cost manufacturing model.

The second path (adoption – re-design), the *new markets path*, was characterised by new value propositions and customer interfaces. As shown above, BP Solar addressed residential customers in a mass marketing campaign and offered convenient solar packages, later in cooperation with The Home Depot (2003–2004). This customer-focused *adoption* provided a temporary 25% market share in California

(BP, 2004). The second milestone of this path was new business-to-business relationships established around 2006. BP Solar cooperated with homebuilders and community developers to address directly private homebuyers in the process of planning and building new homes. This step is an adoption since new value propositions were offered (e.g., convenient access to self-produced green power) based on modified distribution channels, with a rather small number of business model elements being changed. Another innovation targeted commercial customers. 'BP Solar Business Solutions' were based on a variety of contractual and financial settings enabling commercial customers like Walmart to set up medium and large-scale systems, and run their businesses partly on green power. Depending on the respective setting, this model had traits of both an *adoption* and *re-design*; the latter mainly with regard to financing issues because BP had to integrate new financial models which required completely new partnerships, resources, activities, relationships and so forth.

In the last phase of BP Solar's existence, from 2009 to 2011, the two paths merged in a full business model *re-design*: the company had ultimately transformed from an integrated solar cell and module producer with diversified distribution channels into a large-scale project developer which supplied modules as a mass market commodity produced by third parties in low cost economies (Fezzani, 2010; Reuters, 2011; Riddell, 2009). Originally, BP Solar had a fully integrated value chain, but from 2009 the focus was on the downstream end and utility-scale power plants like the 150 MW Moree Solar Farm. This project was announced as Australia's first utility-scale solar farm (BP, 2011c), but was cancelled as the Australian Government withdrew the funding because of excessively high costs and a lack of PPAs (Moree Solar Farm, 2012). In 2010, Fezzani mentioned negotiations about a possible 600 MW solar project (Fezzani, 2010). However, no company reports confirming such plans have been found.

The rationale behind the merged optimisation and new markets paths was confirmed by Fezzani (2010) who pointed out that it is only large-scale projects which provide the demand to fully utilise module production capacities and realise the necessary economies of scale to stay competitive. However, BP Solar's closure shows that the group management was no longer willing to wait until the business environment, especially policy makers and Asian competitors, 'decided' whether BP Solar would file for bankruptcy (as did, e.g., Solyndra and Q-Cells), or would survive the global solar industry shakeout. In this context, one of the former CEO's statements is very telling. He explained that …

> "… the period of economic distress we are experiencing today is a natural and necessary development in the evolution of clean energy. It will help us shake out the weak and ineffective business models … and the poorly capitalized and managed corporations." (Fezzani, 2009; transcribed)

7 Summary and conclusions

Six major business case drivers and two business model innovation paths behind BP's solar business case were reconstructed in an in-depth case study on the British oil giant's solar activities. Twenty-eight annual and sustainability reports from 1998 to 2011 and further backup resources like speeches and press releases were analysed by means of qualitative content analysis to provide a detailed picture of BP Solar, BP's photovoltaics subsidiary which was founded around 1980 and closed in December 2011. The analysis followed an analytical framework from corporate sustainability management research. It concluded that BP applied an accommodative strategy to develop its solar business, i.e. a strategy which …

> "… reflects a rather cautious modification of internal processes and the modest consideration of environmental or social objectives … [and] integrate[s] environmental and social objectives in most of the business processes and maybe partly in the product range, however, *without questioning the revenue logic or the core business as such*." [Schaltegger et al., (2012), p.103; emphasis added]

This conclusion is mainly based on the insight that proactive measures in favour of a solar business case, like achieving (temporary) market leadership, did not unfold their full business model transformation potential (cf. Sommer, 2012). In other words, BP Solar left no mark on the group's central oil and gas business model. However, business model innovation was an important issue within BP Solar itself. Both incremental and radical modifications were applied to improve competitiveness, leading to the partial deconstruction of the formerly fully integrated solar value chain (cf. Bresser et al., 2000; Townsend, 2011). The 'optimisation path' was a transformation from full integration to flexible orchestration of own and third party activities and resources (cf. Schweizer, 2005), while the 'new markets path' introduced completely new value propositions for new customer segments. Both paths converged in the utility-scale project business model – apparently without renewing BP's solar business case.

Moving from subsidiary to group level, it is obvious that BP was and is absolutely dedicated to the oil and gas business, even after the Deepwater Horizon accident in 2010. Alternative energy activities (and rhetoric) were not increased in response to this catastrophe. Instead, BP's reports suggest a strategic backlash against renewable energies and a strategy turnaround with a narrow focus on biofuels, i.e., an alternative that fits well the downstream segments of the group's fossil fuel value chain. This shift was already noticeable in BP's reports from 2007 onwards, i.e., after Browne was replaced by Hayward as Group CEO. Finally, during the Deepwater Horizon aftermath BP focused on rebuilding its reputation as an oil and gas company. The according strategy apparently included renouncing its former renewable energy flagship BP Solar. The annual report of 2011 was clear about the group's unwavering focus on oil and gas exploration and the will to regain its shareholders' trust:

> "*Exploration is our lifeblood.* We had a record year for new access in 2011, gaining 55 exploration licences in nine countries. This opened up around 315,000 km^2 for exploration. We intend to more than double exploration investment over the next three years." [BP, (2012a), p.16; emphasis added]

The fact that BP shut down its solar business and did not increase its renewable energy activities (and rhetoric) after the Deepwater Horizon accident supports the conclusion that BP Solar's reputational business case and its potentially appeasing effects did neither outweigh BP Solar's relatively weak financial business case nor contribute to restoring the group's licence to operate. In this context, the only rational decision might have been to stop the solar business based on two considerations: first, if this business causes opportunity costs compared to the profitable oil and gas business and, second, if certain stakeholders permanently claim that BP's renewable energy business is greenwashing, why then spend money on it? The question arises whether valuation methods other than standard financial assessments would have changed BP's solar business case assessment.

Real options valuation, for example, might be an approach to account better for the great uncertainties and volatility of the solar business (mainly due to policy risks) and the flexibility for managers to respond (cf. Gilbert, 2004). BP Solar's final business model – large-scale project development combined with outsourced manufacturing – might have been a flexible platform for developing a real options portfolio to create both financial and reputational solar business cases.

However, the dominance of the oil and gas business model was limiting the freedom for solar business case experiments [cf. Backer (2009) and her conclusions on Shell's wind energy activities]. The study's content coding showed that BP's sustainability reports contain many defensive statements that put the technical and business potential of solar energy into perspective as against fossil fuels. However, in this context it is not the dominance of the oil and gas businesses that is surprising, but the fact that BP was engaged in photovoltaics for more than 30 years *despite* this dominance.

One explanation for this continuity might be that BP Solar was a pure reputation-building investment (maybe even greenwashing). Beder (2002), for example, argues that a company spending hundreds of millions of dollars on a rebranding campaign ('beyond petroleum') would also invest hundreds of millions in its solar business just to pretend it is committed to building a sustainable energy future. Another explanation might be that BP's decision makers believed in solar power. This latter thesis might be supported by the hard figures, for example reaching one billion dollars annual revenue in 2007 and capacity sales of 325 MW in 2010, as well as the many efforts to improve the solar business model. Moreover, one must not forget that BP Solar was managed by specially trained and nominated CEOs who had to deliver results – i.e., at least Mike Petrucci (since 2010), Reyad Fezzani (2008–2010) and their predecessors might have been really dedicated to creating a solar business case, regardless of the 'natural' tensions between the fossil and the green businesses, which had to coexist within the BP group.

A final explanation can and shall not be given due to limitations of method, of which the main one is the nature of the data sources chosen. The section on method has discussed the advantages and shortcomings of analysing corporate publications. Ultimately, it has to be accepted that this study is based on an outsider perspective and has to account for communication biases between sender and recipient.

Another kind of limitation refers to the scope of the analytical framework which does not include external parameters and contingencies, such as the fact that renewable energies are still policy-dependent. Policy decisions are also the cause of the extreme cost competition in the solar industry. Nor is competition, finally, covered as a source of business case effects. However, the approach chosen for the present piece of research with its combination of the extended business case for sustainability framework and qualitative content analysis was well suited to the reconstruction of BP's solar business case, its strategic drivers and business model innovations.

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Notes

1 The 'Wayback Machine' stores websites since 1996. For http://www.bpsolar.com archived websites are available from 1997 to 2012; see http://web.archive.org/web/*/http://www.bpsolar.com.

2 It is important to note that this assessment does not reflect BP's group-level environmental or sustainability strategy.

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Beyond Technology Push vs. Demand Pull: The Evolution of Solar Policy in the U.S., Germany and China

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Beyond Technology Push vs. Demand Pull: The Evolution of Solar Policy in the U.S., Germany and China

Abstract: To explain and promote the adoption of new technologies, researchers have debated the relative importance of technology push and demand pull factors (e.g., Schmookler, 1966; Mowery and Rosenberg, 1979; Peters et al, 2012). Here we examine a crucial problem of contemporary innovation policy — promoting the adoption of renewable energy to reduce anthropogenic global warming — that challenges prior models for large scale innovation adoption. From the recommendations of Mowery, Nelson and Martin (2010), we develop a typology of technology push and demand pull policy design principles for renewable energy adoption. We use these principles to analyze a sample of 79 solar energy policies from 1974 to 2011 in the U.S., Germany and China. To go beyond the push/pull dichotomy, we also map these policies to the (solar) value chain. From this, we suggest additions to the model of technology push and demand pull — distinguishing between direct and indirect push and pull — to explain the success of renewable energy policies.

1. Introduction

An ongoing debate for the timing of adoption of new technologies has been over the relative contribution of two types of factors, broadly categorized as "technology push" and "demand pull." The former factors include both the availability of a new technology, its maturity, and its relative advantage, while the latter relate to the degree of unmet need and the awareness of the new technology. This contrast has been drawn in predictive studies for innovation adoption (Cohn, 1980) and normative recommendations to managers (Abernathy and Clark, 1985). For public policy research, the relative importance of these two categories has suggested efforts to support R&D and other technology development, or to encourage demand through subsidies and other incentives (e.g. Mowery and Rosenberg, 1979; Elder and Georghiou, 2007; Nemet 2009).

A current example that has renewed this debate has been over policies to promote the deployment of renewable energies. While such policies are often justified in terms of economic development, the recent push has come due to increased concerns about global warming attributed to greenhouse gas emissions from fossil fuels (e.g. Hargadon, 2010). The challenge is particularly daunting because "The scale of this transformation dwarfs that of most prior problems of technology policymaking. Success requires the development, commercialization, and diffusion of many ‘suites’ of complementary energy technologies throughout society.” (Huberty and Zysman, 2010, p.1027)

In a special issue of *Research Policy,* three senior innovation scholars concluded that “strong governmental technology policy is an essential component of any portfolio of policies aiming to stop and reverse global warming” (Mowery, Nelson and Martin, 2010, p.1011). However, they argued that it is inappropriate to emulate previous technology-push approaches:

> [H]alting or reversing global warming almost certainly cannot be achieved solely through ‘supply-side’ policies and the development of technological ‘solutions’. Indeed, one of the largest dangers created by the Manhattan or Apollo metaphor is that it may be adopted by politicians seeking to avoid the far more painful demand-side policies aimed at changing human behavior. … Public policies to support the development and deployment of technological solutions to global warming are urgently needed, but these programs must differ in design from the “big push” programs exemplified by the Manhattan or Apollo projects. (Mowery et al., 2010, p.1012)

The adoption of solar energy is an example of the broader class of technology adoption problems that may depend on both technology push and demand pull factors. As with other forms of technological adoption, policies to encourage solar adoption have addressed both the technical risks (technology push) and overcome the objections of adopters (demand pull).

Here we review the prior research on innovation as it relates to the technology push vs. demand pull debate, as well as the issues that have been previously identified for the adoption of renewable energy (RE). We answer the call of Mowery, Nelson and Martin with what we believe is the first operationalization of their policy proscriptions, by using their analysis to develop an 18-point typology of push and pull policy design principles and conditions for RE adoption. We then use this to code longitudinal data on 79 solar photovoltaic (PV) policies from 1974-2011 for three major economies: U.S., Germany, and China.

From this, we suggest that the theoretical model of technology push vs. demand pull is incomplete in explaining the adoption of renewable energy in two ways. First, we suggest extensions to the often-studied direct approaches to technology push and demand pull are policies that indirectly achieve the same goals. Secondly, we identify the role of generic complementary assets as a crucial indirect technology push factor that should be considered in renewable energy and other innovation policies.

2. Push and Pull Factors in Promoting Innovation Adoption

The debate over the relative importance of technology push and demand pull dates back 50 years (Griliches and Schmookler, 1963; Schmookler, 1966; Mowery and Rosenberg, 1979; Scherer, 1982; Jaffe, 1988; Chidamer and Kon, 1994).[1] Both have also been often used in policies promoting renewable energy (Loiter and Norberg-Bohm, 1999; Nemet, 1999).

Determining the relative importance of these two factors has two major implications. The first is the causal or explanatory, i.e. determining which factor is more important in explaining the successful (or failed) adoption of a new technology. Flowing from this is the second or normative dimension: what policies should a government adopt if it wishes to promote technological progress and the consumer (or producer) benefits that accrue from such adoption. While for decades the two camps argued for either the technology push or demand pull hypothesis, to date it is widely acknowledge that a more systemic perspective is necessary where both technology push and demand pull policies are important (Nemet, 2009; Mowery and Rosenberg, 1979; Sagar and van der Zwaan, 2006; Taylor, 2008).

2.1 Technology Push

The arguments for technology push contend that whether at the level of a specific inventor or firm (Abernathy and Clark, 1985) or at the aggregate level of an industry (Utterback, 1974), it is

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[1] The debate tends to assume “a linear model of the innovation process with science at one end and markets or users at the other” (Chidamer and Kon, 1994, p. 95). For a rare exception, see the systems perspective of Edquist and Hommen (1999).

the rate of technological progress that determines the adoption and impact of new technologies. In most cases, the importance of industrial R&D is dependent on (or even subordinate to) the role of basic science in enabling this progress.

Perhaps the earliest advocate of this view was Schumpeter, who in his entrepreneurial (Mark I) and corporatist (Mark II) theories argued that radical and incremental innovation expand the base of technology which displaces existing technologies and firms. Some versions of this perspective adopt a weak form of technological determinism, assuming the direction (if not rate) of technological progress to be inevitable and perhaps even exogenous to the efforts of individual firms (Schumpeter, 1934, 1942; Nelson and Winter, 1982; Jaffe, 1988; Chidamer and Kon, 1994; Malerba and Orsenigo, 1996).

Some supporters of this perspective have made narrower arguments. On the one hand, the ability of a firm to deploy radical innovations may depend on a configuration of internal competencies to support a technology push approach (Abernathy and Clark, 1985). On the other hand, the interest of buyers in using a technology may depend on the cumulative incremental improvements in cost, features or quality (Mowery and Rosenberg, 1979). Still other researchers have examined the interdependencies within technology push. For example, Meyer (2000) concluded that within a technology push approach, technology can pull science or that science can push technology.

2.2 Demand Pull

The idea that new technologies are not endogenously created, but in fact are shaped by the nature of demand can be traced to the work of Jacob Schmookler (Griliches and Schmookler, 1963; Schmookler, 1966). As Scherer (1982, p.225) put it, “Schmookler’s main contention, contrary to the prevailing emphasis on changes in scientific and technological knowledge, was that demand played a leading role in determining both the direction and magnitude of inventive activity.” Schmookler (1966) and Scherer (1982) found that demand (as proxied by capital investment) led technical invention (as measured by patents).

In a review of 17 studies of innovation adoption, Utterback (1974, p.621) concluded:

> Market factors appear to be the primary influence on innovation. From 60 to 80 percent of important innovations in a large number of fields have been in response to market demands and needs. The remainder have originated in response to new scientific or technological advances and opportunities.

While studies of the impact of commercial or consumer demand on technological progress can inform public policy, a more direct link can be found in the role of government procurement. Edler and Georghiou (2007) discussed how EU governments could use public procurement to support national technology development and commercialization efforts.

In response to such studies, in their critique Mowery and Rosenberg (1979,p.105) argued that the role of demand was “overextended and misrepresented.” Even at that early stage in the development of renewable energy, they concluded:

> The point is that in certain areas, such as alternate energy or antipollution technologies, industries may simply lack sufficient R&D resources or the necessary market-generated incentives. (Mowery and Rosenberg, 1979, p.148)

2.3 Push and Pull Factors in Promoting Renewable Energy

Both directly for renewable energy adoption and through analogous reasoning of successful U.S. and U.K. technology policies, Mowery et al. (2010) support the role of the national government in funding technology development to enable subsequent adoption. Technology push policies are also considered to be important for filling in the gaps in basic technological knowledge in the context of renewable energy (Mowery and Rosenberg, 1979).

However, there has been also a recent emphasis on the use of demand-side policies. For example, an official UK blue-ribbon commission argued that strict regulatory standards to mandate RE use would “stimulate innovation by reducing uncertainty for innovators” (Stern, 2007, p.452). Similarly, Hargadon (2010, p.1025) argued that “[d]emand-side policy incentives are considerably more effective at promoting the innovation and diffusion of renewable energy than R&D investments,” a conclusion similar to that of an earlier study of other environmental technologies (Taylor et al., 2005). In his study of wind generation, Nemet (2009) found that demand-side policies made California the world’s leading market for wind power in the 1970s and 1980s, but encouraged incremental over radical innovation. Peters et al. (2012) identified country-level spillover effects induced by demand pull policies.

Overall, studies on renewable energy adoption have suggested the need for a systemic approach by creating policies for both technology push and demand pull (Mowery et al., 2010; Peters et al., 2012; Taylor, 2008). However, only a few empirical studies on RE take such a systemic approach. One was Taylor (2008) who identified the importance of “interface improvement” in California solar policy as between the push and pull dichotomy Another is Peters et al. (2012) who focused on aggregate level of policy determinants without determining the effect of specific policy instruments. Our aim is to contribute to this research through a cross-country comparison of major RE markets applying a broad unit of analysis covering push and pull, and identifying a broader category of indirect push and pull policies.

3. Research Design

We are interested in the production and use of photovoltaic (PV) generating equipment — the direct conversion of solar energy into electricity — first made practical with the first silicon solar cell in the 1950s — which has been a major emphasis of RE policy and investment since the 1970s.[2] We focus on three countries: the U.S., Germany and China, which have played a leading role in the deployment of solar energy. Based on the needs of its (government-funded)

[2] At the end of 2011, 94% of the world’s supply of RE generated electricity came from hydroelectric, wind and solar PV (Ren21, 2012), but policies promoting RE adoption have de-emphasized hydroelectric because of limits on the availability of new generating sites.

aerospace industry, United States was the technological leader and provided early niche markets from the 1960s until the 1990s. Through policy innovation, Germany has been the largest market in the world during the 21st century. Finally, with massive public investment in manufacturing companies at a time of credit contraction in the West, since 2009 China led the world in PV manufacturing capacity, as measured both by annual output and capital investment.

3.1 Data

The present paper is based on a secondary dataset of global renewable policies since 1974 that were compiled by the International Energy Agency (IEA) from 82 countries, including 28 IEA members and 54 other countries. The database contains nearly 1,000 policies with variables such as country, jurisdiction, year of implementation, policy status, policy type, objectives and a description. From the IEA database, we first selected all RE policies from our three countries (175 in total). Then, we selected only policies that directly relate to photovoltaic solar energy; this includes both solar-specific policies as well as broader RE policies which cover solar PV among other technologies. Overall, this narrowed the 175 RE policies to 79 policies: 49 U.S., 17 German, and 13 Chinese policies (Table 1). For comparability between countries, we coded only national policies (this also covers national policies being operationalized on the state level).

Insert Table 1 here

The selection of the policy sample was subject to two major challenges: (1) comparability and (2) completeness. Regarding comparability, each entry in the IEA database could directly refer to an individual policy (e.g. U.S. “PURPA”), or to a larger “policy package” that covers many individual policies (e.g. U.S. “EPAct 2005”); such policy packages are particularly common in the U.S. To assure comparability, we coded only individual policies.[3] For complex

[3] To code packages, we separated IEA entries representing policy packages into individual policies, using the

packages, we consulted third-party documents (such as the text of the law) to verify and better understanding policy packages and the individual policies contained therein. Sometimes, this led to the identification of additional policies originally not described in the IEA description of the policy package, which we then added to our analysis for the sake of completeness.

In parallel to the IEA database, we developed from published sources (in the respective national languages) a chronological history of the major milestones of the solar policy in the three countries. We used these histories to supplement our analysis, but did not explicitly code events or policies outside the IEA data. For the U.S, this included Federal policies listed in the DSIRE database, various congressional reports, and reports from other research institutes (e.g., Cunningham and Roberts, 2011; Lazzari, 2008). For Germany, we used various German-language sources, mainly policy monitoring reports issued by ministries and research institutions as well as original policy documents such as legal texts and official program descriptions. For China, we supplemented the IEA database with Chinese government website information on solar policy as well as other relevant information obtained through limited interviews with government officials and professionals in the solar field.

3.2 Coding

Based on a historical analysis of U.S. and U.K. policies related to agricultural, biomedical and information technologies, Mowery, Nelson and Martin (hereafter MNM) made a series of recommendations for effective RE policies (Mowery et al., 2010, pp.1019-1022). Here we offer what we believe is the first effort to operationalize the MNM design principles for use in policy assessment. To operationalize and apply these principles to the empirical data of the IEA database, we developed a coding system for qualitative content analysis using an iterative

database entry as the starting point to identify individual policies. Although we did not use the packages for coding, to assure transparency of data coding, in Tables A.2-A.4 we group the policies as reported in the IEA database.

process of coding and re-coding as recommended by Eisenhardt (1989).

Adapting the definitions of Edler and Georghiou (2007), we divided the MNM proscriptions into eight *technology push* (T1a[4],T1b,T1c,T1d,T2,T3,T4,T5) and five *demand pull* (D1,D2,D3,D4,D5) categories. A third category covered five principles that were *policy conditions* (C1,C2a,C2b,C3,C4,C5) that modify push or pull principles, such as long-term support (five years or more). Across these three categories, we identified 18 separate principles of the MNM policy proscriptions (Table 2; see also Appendix A.1).

Insert Table 2 here

We then coded each of the 79 policies as to whether they matched one or more of the 18 principles (as reported in Appendices A.2-A.4). We discussed our preliminary coding decisions to resolve ambiguity in the coding and assure consistent application of the coding rules. We used these discussions to revise the coding decisions, the coding rules or both.

Finally, to identify the importance of government policies in commercialization, we sought to identify the primary focus of each policy by the stage of the solar value chain that it addressed (Figure 1). Using an iterative approach, we refine our classification to six stages in the value chain: basic research, applied R&D, manufacturing, interface improvement, deployment, and use, as well as a seventh category (demonstrations) that may span one or more of these stages[5]. Table 3 shows examples of actors, activities and policies for each stage.

Insert Figure 1 here

4 Although MNM does not explicitly call for public performance of publicly funded R&D, their earlier work has clearly supported government funding of public basic research (e.g. Mowery et al., 2004: 25-26; Salter & Martin, 2001). We thus interpret MNM as encouraging privately performed R&D in addition to publicly performed R&D, and thus use T1b and T1c for the former and T1a for the latter. Consistent with David (2004), we classify research by private universities and other non-profit organizations as "public."

5 We classified manufacturing R&D as "R&D," limiting "manufacturing" to operation or scale-up. We reserved "Interface Improvement" for policies that bridged between the manufacturer and user (such as skilled installation; cf. Taylor, 2008) and also the resolution of adoption barriers such as technical interconnection, building codes or installation permits.

Insert Table 3 here

4. Analysis of the Policies

4.1 United States

As the country that both invented PV and had the largest market, it is not surprising that the U.S. had the earliest and widest range of policies, including both push and pull policies.

4.1.1 Technology Push Policies

Although the U.S. government procured solar cells in the 1960s for satellites and other space applications, terrestrial solar policy has its roots in the 1973 oil embargo. One of the first policy responses of the U.S. government to the oil crisis was to dramatically increase funding for research and development activities (T1). This led to the enactment of the Solar Photovoltaic Energy Research, Development and Demonstration Act of 1974 (1974 Act), which created the first sizable research program for solar energy with expenditures of $1 Billion (plus another $1.5 Billion in the 1978 act) with a focus on basic research and broader R&D (42 USC §5581; 42 USC §5551). The act also created the Solar Energy Research Institute (SERI) which began operations in 1977 and became the National Renewable Energy Laboratory in 1991. Another research program of that time was the NASA-led Low-cost Silicon Solar Array (LSSA) project in which U.S. government spent $235 million from 1975-1986. Subsequently, since 1996, major research policies in solar has been administered by the Department of Energy under the umbrella name of Solar Energies Technologies Program (SETP) (later integrated in the SunShot Program), including such policies as the Solar America Initiative and Solar Decathlon. Most of these publicly funded R&D programs include both publicly performed (T1a) and private performed research (T1b).

Beginning in 2007, the Technology Commercialization Fund (TCF) aims to link research and development to commercialization by requiring matching private investments; other government programs also had matching requirements to encourage private investment (T1c) (cf. Jaffe et al., 2005, p.170). Subsequent research initiatives to promote radical innovation — such as Advanced Research Projects Agency–Energy (ARPA-E) and the Energy Frontier Research Centers — can be considered examples of the principle of “no public funding of marginal improvement” (T1d).

No policies studied explicitly provided for “broad research availability” (T2), although we believe that in most cases a policy of knowledge dissemination was implicit: any non-classified research performed at U.S. public labs is by law available to the public, while contract research (particularly by universities) tends to be published in open literature with acknowledgement to Federal funding. We found only one technology competition (T3), although the government used competitions to encourage improve capabilities further down the value chain, with programs such as the Solar Decathlon, “America’s Most Affordable Rooftop Solar” Competition, and the Solar America Cities awards.

U.S. policies for technology demonstration (T4) were part of either broader R&D programs (e.g. the 1974 Act) or larger policy packages addressing both push and pull (e.g. Solar America Initiative; Energy Independency & Security Act of 2007).

It was hard to find examples of learning in use (T5) that feed operational experience back to R&D. One of the few exceptions was the Solar Photovoltaic Energy Research, Development and Demonstration Act 1978:

> “to select, as soon as he deems it feasible, a number of the applicants […] and enter into agreements with them for the design, purchase, fabrication, testing, installation, and demonstration of photovoltaic components and systems. Such selection shall be based on the *need to obtain scientific, technological, and economic information* from a variety of such systems under a variety of circumstances and conditions” (42 USC §5584; italics added).

The ability of firms to supply technology depends on more than just doing R&D. So in addition to R&D support, policies supported firm efforts to develop manufacturing processes and capacity, either through financial incentives (e.g. Renewable Energy Innovation Manufacturing Partnership Program; Advanced Energy Credit for Manufacturers) or nonfinancial subsidies such as workforce training initiatives (e.g. Green Jobs Act). Although not corresponding to an MNM recommendation, about 12 percent of the US policies had such indirect technology push effects.

4.1.2 Demand Pull Policies

The U.S. lacks "Regulatory performance targets" (D1) at the national level, except for Federal RE government procurement goals based on executive orders (discussed below). However, beginning with Iowa in 1983, the Renewable Portfolio Standard (RPS) was implemented in the majority of states and established ambitious targets for RE to comprise up to 30 percent of electricity consumption by 2020 (C2ES, 2012); although state level policies, the widespread adoption has given RPS almost national significance, as evidenced by proposals for a federal RPS (Fischlein and Smith, 2013).

Instead, beginning with the Energy Policy and Conservation Act (EPCA) of 1975, the primary U.S. approach for incentivizing renewable energy (including solar) came with tax credits and other targeted financial incentives (D2) for equipment purchase and installation. The initial investment tax credits were provided both to residential and commercial buyers (e.g. Business Energy Tax Credits). The portfolio of tax incentives was further diversified through the EPAct 1992 which introduced the Production Tax Credit (PTC) which, instead of subsidizing equipment purchase, provided a subsidy for each kilowatt hour of RE generated. Also other programs introduced financial incentives such as grants via the Renewable Energy Production Incentive. Finally, the EPAct 2005 created a Loan Guarantee Program for Innovative Energy Technologies that became particularly important through the American Recovery and Reinvestment Act (ARRA) which appropriated $2.4 Billion in funds to cover $16 Billion in loan commitments (Brown, 2012, p.6f).

In proposing policies for "pricing externalities" (D3), MNM identified a long-standing concern by renewable energy supporters that the transaction price for fossil-fuels does not reflect the full social costs of such sources — including factors such as pollution and greenhouse gas emissions (CBO, 2012, p.8). A proposed carbon tax — the America's Energy Security Trust Fund Act — was introduced in the Congress in 2007 and 2009 but never enacted. However, the price of fossil fuels were raised when oil and gas tax breaks were cut as part of the Energy Improvement and Extension Act of 2008 (Lazzari, 2008)

A commonly used category is government procurement (D4) which addresses the last two phases of the value chain depending on whether procurement covers technology equipment or actual electricity. Examples included the EPACT 2005, Solar Energy Research and Advancement Act, Solar America Initiative, and various presidential executive orders, but the magnitude of such procurement was relatively small compared to the U.S. energy industry.

Public dissemination programs (D5) are an established part of U.S. policies, usually not as a standalone activity but rather a complement to demonstration projects (T4) or financial incentives (D2). Exemplars are the Tribal Energy Program providing education and training for (potential) early adopters, and Solar Decathlon which enabled public visits of prototypes of developed energy systems.

4.1.3 Conditions

Perhaps the most important condition of the MNM framework, "long-term support" (C1) reveals a key weakness of U.S. solar policies and energy policies more broadly. Less than half of the policies were stable for five years or more, with the majority characterized by continued threat of phasing out, temporary extension, changes in eligible technologies, or changes in budget allocations. Many policies (such as ARRA) were enacted only for few years, with some be extended shortly before (or sometimes after) the planned phase-out, creating uncertainty for all parties involved. Another form of inconsistency can be seen in the Production Tax Credit (PTC) which covered solar photovoltaic technology only from 2004 to 2005. A third form of inconsistency has come with long-term policies that have only short-term budget allocations that need to be renewed every few years. Such policy inconsistency drove Luz International, the largest U.S. developer of solar farms, into bankruptcy in 1991 (West, 2011).

A further condition is decentralized programs (C2a) and centralized leadership (C2b). Here, U.S. policies can be characterized as split between purely federal administered (and thus central) leadership (C2b) and policies where federal governments leave it to the individual states to operationalize and monitor the programs (C2a,C2b). The former includes most of the energy tax credits (e.g. Residential Energy Tax Credit), while the latter includes the State Energy Program which provide federal funds to states to fulfill the program goals.

Most U.S. policies cover several renewable energy technologies and thus represent "technological diversity" (C3). However, early US policies focused explicitly on solar technologies (whether PV or including solar thermal) — particularly in the 1970s, which brought the Solar Photovoltaic Energy Research, Development and Demonstration Act. Except for the Solar America Initative and Solar Decathlon (all managed under DoE's former Solar Energy Technologies Program), most 21st century policies have been technology neutral. In fact, the Energy Policy Act of 2005 expanded eligible technologies from "renewable energy" to "clean energy" including nuclear, clean coal, and carbon capture and storage technologies;[6] while this further increases technology diversity, it could dilute the focus and resources available for RE.

[6] Efforts have been made in the U.S. to reposition nuclear power as a "clean" technology (Garud et al, 2010), which could force traditional renewable energies to compete for subsidies and other policy support.

Finally, policies have demonstrated global/international cooperation (C4). Early in U.S. support for renewable energies, the Solar Energy Research, Development, and Demonstration Act of 1978 created an “International Photovoltaic Program Plan” for “stimulating exports for United States manufacturers” which was administered by SERI (SERI, 1979, p.118). The successor organization, the National Renewable Energy Laboratory, pursued both bilateral and multilateral international activities (that included Germany and China), for instance to facilitate the development of solar standards. Going beyond export promotion, the Energy Independence & Security Act (EISA) of 2007 institutionalized mechanisms for international policy analysis, collaboration with foreign governments, and improved “energy diplomacy”.

4.2 Germany

While Germany pursued both push and pull policies, it is best known for its Feed-in-Tariff demand policy innovation, which encouraged private investment in RE generation equipment.

4.2.1 Technology Push Policies

The German interest in renewable energies emerged in the 1970s as a reaction to the oil crises and increasing concern about nuclear power (Wüstenhagen and Bilharz, 2006). The most important technology push policy for solar PV-related R&D identified in the IEA database is the Federal Government’s Energy Research Program. Implemented by different federal ministries (Ministry of Economics (BMWi); Environment (BMU); Agriculture; and Education and Research), it is a framework that sets priorities and provides funding for public and private research projects (T1a, T1b). Today, the government pays up to 50% of research costs under the Energy Research Program and companies have to match the public funds with own investments (T1c), while academic basic research is funded up to 100% (T1a). On average, PV received 32% of BMU spending for renewable energy research projects between 2004 and 2011. In 2011, this funding reached an all time high of €74 million (BMU, 2012).

The second major technology push policy has been government-funded research, particularly at the nonprofit Fraunhofer Institute for Solar Energy Systems (ISE), Europe's largest solar research center. In 2011, 50% of its funding came from industry, 45% from EU and federal government project funds, and only 5% from permanent government funding (Fraunhofer ISE, 2012). Thus, Fraunhofer ISE made the shift from public to partly private funding as recommended by MNM (T1c). It specialized in transferring the results from basic research and public-private R&D, e.g., through demonstration and learning-in-use activities (T4, T5). All R&D policies made reference to broad information dissemination programs to speed up the diffusion of research outcomes within the PV industry (T2). Policies promoting R&D contests (T3) were not found.

When coding push and pull policies, we found examples of hybrids. The 1,000 Roofs Solar Power Program of 1990 combined publicly funded and performed evaluation research (T1a) and subsidies for private, small-scale installations (up to 70% of the investment cost) (D2). The program served as a practical field test of the commonly available technology and generated valuable information that was fed back to R&D (T5). Users receiving subsidies were obliged to collect performance data for at least five years, which were then analyzed by Fraunhofer ISE; some of these early installations are still monitored today. These data collection and analysis efforts not only served as feedback to R&D, but were also published and broadly disseminated to inform potential users and other researchers (D5).

4.2.2 Demand Pull Policies

Germany's demand pull approach to supporting the deployment of PV technologies emphasizes financial incentives and subsidies from institutions such as BMWi and BMU, often involving the state-owned bank for economic development (Kreditanstalt für Wiederaufbau, KfW) (D2). Grants to support the purchase and installation of PV equipment were common in 1990s, with the 1,000 Roofs Program, the 100 Million Program and in part the 100,000 Roofs Solar Power Program. The other long-standing policy was through government-subsidized loans, which were available from the KfW since the 1990 Environment and Energy Saving Program (ERP) — and after 2009, under the new Renewable Energies Program.

However, the most important financial incentives for the deployment of PV equipment in Germany are regulated feed-in-tariffs (FiT) (D2). The Electricity Feed-In Law enacted in 1991 was the world's first FiT policy, and required grid operators to pay premium prices for green electricity supplied by producers of RE. Local utilities also introduced additional Full Cost Rates subsidies starting in 1993, but both the Electricity Feed-In Law and the Full Cost Rates were replaced by the Renewable Energy Sources Act (EEG) in 2000. Reflecting cost reductions due to learning effects, the EEG's tariffs are regularly reviewed with tariffs changed at least in seven out of the twelve years since 2000. PV tariffs were reduced several times in order to moderate the German PV boom. As an alternative, producers can sell their electricity directly to the market through different Green Power marketing instruments that allow producers to charge a price premium to cover additional costs of producing and distributing RE (D2). Since green direct marketing came up in the mid-1990s, federal and state-level ministries and public agencies increasingly purchase green electricity as a form of government procurement (D4).

Clear evidence for the last MNM demand pull category, public dissemination programs (D5), was found in at least two policies: the 1,000 Roofs Program directly targeted lead users and provided information on state-of-the-art PV technology, installation, and deployment on private buildings. The BMU's Climate Protection Investment program includes wide public communication on the possibilities of emission reductions which in some cases lead to sustainable energy concepts which integrate PV technology. As in the U.S., Germany did not adopt the policy principle of pricing externalities (D3) suggested by MNM.

The German demand pull policies related to PV covered the three final stages of the value chain (i.e. deployment and use), with the greatest emphasis (in policy and funding) for deployment of new solar panels. The database identified four policies supporting interface improvement, through codes regulating the modification of buildings and grounds for renewable energy purposes, as well as services such as architecture and engineering. Additionally, the Energy Industry Act and the EEG require that grid operators provide connections for RE generation. The final (use) stage has only recently gained support through a new EEG mechanism rewarding direct consumption of self-produced solar power.

4.2.3 Conditions

Regarding policy conditions in Germany, both the technology push and the demand pull policies are rather stable and long-term oriented (C1). The government has funded research at Fraunhofer ISE since 1981. On the demand side, while FiT and other policies are regularly amended, most have been in effect for a decade or more.

From an organizational viewpoint, Germany's federal PV policies are only in some cases based on decentralized structures (C2a), e.g., in the case of the 1,000 Roofs Program which was initiated and partially financed by a federal ministry, but implemented and co-financed by state ministries and agencies. A decentralized approach can also be found with government and nonprofit R&D funding. The dominant demand pull policy portfolio is instead based on centralized federal leadership (C2b) with policies such as the EEG initiated and controlled at the national level.

Technological diversity (C3) is commonly supported by German policies: in most cases, PV is part of a broader portfolio of technologies to provide sustainable energy and combat climate change. However, some policies were exceptions in focusing on or favoring PV, such as the 1,000 and 100,000 Roofs Programs, or the Full Cost Rates programs. The MNM condition of global cooperation (C4) was not identified in the database.

4.3 China

The Chinese PV industry is export driven, with about 90% of the industry outputs exported abroad.[7] The history of Chinese solar policies is a recent one with a rather limited set of policies implemented. Unlike in the U.S. and Germany, the initial emphasis was on demand pull before technology push. To be consistent with our earlier discussions on the two other countries, we will discuss technology push policies first.

4.3.1 Technology Push Policies

Among the few Chinese technology push policies related to PV, the emphasis was on government-funded R&D (T1a, T1b). The national level strategic initiatives that can cover R&D support to PV industries include the national "973 plan" which focuses on basic research such as research on thin film battery (1997), national "863 plan" which focuses on advanced technology development and support the commercialization of PV technologies (1986), and national "key projects support plan" with funding available to research in PV technologies and its commercialization. The Renewable Energy Law amendments in 2009 initiated a Special Fund for renewable energy that will finance industry research and development (T1b). The two other policies that foster technology development in renewable energy include the Medium and Long Term Development Plan for Renewable Energy (2007) and the International Science and

[7] Interview with senior official, China Ministry of Science and Technology, May 27, 2011.

Technology Cooperation Programme for New and Renewable Energy (2008) (T1a, T1b).

Among the relevant policies listed in the IEA database, we found that only the 2006 Renewable Energy Law and its amendments in 2009 addressed broad knowledge dissemination (T2), the International Science and Technology Cooperation Programme mentioned technology contests (T3). No evidence of technology demonstration (T4) or learning in use (T5) was found.

4.3.2 Demand Pull Policies

Most of the demand pull policies in China fall in our categories of regulatory performance targets (D1) and targeted financial incentives (D2), with many recent policies focusing on D2.

The history of the regulatory performance targets (D1) related solar policies goes back the earliest RE policy seen in China: the Brightness Programme. Started in 1996, this program sought to electrify towns and villages in remote areas by using wind, solar and other renewable energy sources, and remains in effect today. Only in 2003 did China create preferential tax policies to encourage foreign investment into RE enterprises and thus to source foreign knowledge on production and installation. This was the first policy to use targeted financial incentives (D2), offering income tax cuts for the producers and consumers of renewable energy, as well as a reduction of the import tax for “green” equipment. Later on, most policies used financial incentives, such that 11 of the 13 policies cited from the IEA database fall in the D2 category.

The first overarching policy for encouraging domestic demand for RE did not come into place until 2006. It was the Renewable Energy Law (2006) by which RE became the preferential area for energy development. Therefore grid access was guaranteed (i.e. interface improvement) and national targets for energy production from RE sources were set (D1). At the same time, this policy was the starting point for very dynamic RE policy development in China. One year later

(2007) the National Climate Change Programme set an energy efficiency objective of reducing energy consumption per unit of GDP by 20% by 2010 and of quadrupling GDP between 2000 and 2020 while only doubling energy use, for combating climate change (D1). The government took measures to close small, less efficient industrial facilities in sectors including iron and steel, cement, aluminum, copper, glass or ceramics. All output from renewable power generation projects can be sold at guaranteed prices to the grid company, where prices will be determined by the price authorities of the State Council. Grid operators will be able to recover extra costs associated with this regime through their own selling prices (D3). Still in the same year — as a consequence of the program — the government set medium and long-term goals for capacity installation for each RE technology: solar PV 1.8 GW; hydro 300 GW (D1). In 2009 the renewable energy law was modified with adjusted premiums and additional research programmers in off-grid RE solutions.

Since 2008, the national and provincial governments established various programs to stimulate RE adoption through financial incentives (D2), such as the national level Solar Power Roof Plan in March 2009.

The Golden Sun Programme was proposed in July 2009, with a goal of 600MW of installed solar PV capacity across China. The program has provided grants both at national and provincial levels to subsidize capacity installation and preferential electricity tariffs (D2), and includes demonstration projects to disseminate knowledge about existing technologies (D5). For these projects, the central government subsidizes up to 50% (on-grid) or 70% (off-grid) of the entire installation costs and requires that electricity utilities in the area purchase the extra capacity generated by the project at unit price similar to power generated from other sources (such as coal). The Chinese government at both national and provincial levels has extensively used demonstration project (D5) as demand pull, such as the Brightness Programme, and the Golden Sun Programme.

In 2011, the central government considered a feed-in-tariff to set the price of electricity generated by sun power at 1.09 yuan/kWh; although 3 times as expensive as power generated by coal, it was still not enough to allow Chinese manufacturers to sell their equipment domestically at a profit (Zhang, 2010). In 2011, the Solar PV Feed-in-tariff Policy took effect (D2) for solar PV projects (approved before July 2011 and put in operation within the same year) with a 1.15 yuan/kWh tariff (18 USD cent equivalent) .

4.3.3 Conditions

The majority of Chinese PV policies emphasized both centralized leadership (C2b) and decentralized implementation of PV programs (C2a). With a strong planned economy in history and a powerful central government in place, it is also common to see some of the policies aim for a long term (C1) such as the Medium and Long Term Development Plan for Renewable Energy, the National Climate Change Program, and Renewable Energy Law. In addition, eight out of the fourteen polices cited in the database mention technology diversity (C3), suggesting the determination of the Chinese government in promoting a range of renewable energy approaches. For global cooperation (C4), the International Science and Technology Cooperation Programme for New and Renewable Energy in 2008 sought to boost technological development, introduce cutting-edge technologies in the national market, attract overseas scientists and develop exchange programs with international research centers.

5. Analysis

5.1 Commonalties of Policy Choices

In Table 4 we summarize the prevalence of the various MNM policy principles and the associated value chain stages from the IEA data for the three countries.

Insert Table 4 here

Each country differed in their mix of push and pull strategies:

- Germany emphasized pull very early and throughout, but later added a limited number of push policies. However, the expenditures for pull policies are the largest within Germany, and the largest pull expenditures among all three countries.
- While the U.S.'s initial policies included both push and pull, new policies emphasized pull until the mid-1990s, and then most policies combined push and pull elements.[8]
- China's formal (IEA) policies favor pull, with technology push largely absent from later policies. However, those announced policies do not acknowledge China's sizable supply push investments in manufacturing, as discussed below.

In the average across all countries, the MNM technology push policy most commonly used is the provision for *publicly performed R&D* (T1a) — although not explicitly identified by MNM — and *public funding of private R&D* (T1b) with 28 percent and 26 percent, respectively; T1a and T1b are also the most consistent push policies across the countries. Several categories were difficult to measure from the policy database, such as the use of public funding for private R&D and the MNM ban on *funding marginal improvements* (T1c), while our database of public policies only identified *private R&D funding* (T1b) when it was a condition of receiving public funds.

On the demand side, the most common policies are *financial incentives* (D2) used on average 58.2% of the time — although each country used a different form: tax credits in the U.S., a feed-

8 Jaffe et al (2005) looks at the proposed 2004 U.S. budget related to GHG reduction and finds the push/pull numbers to be comparable ($1.3 vs 1.0 billion); within RE-specific policies, there's a slight bias towards R&D over pull policies ($430 vs. $300 million).

in-tariff for Germany and a mixture of incentives in China.[9] Both China and the U.S. made use of *regulatory performance targets* (D1) (i.e. RE power quotas), and the U.S. also frequently used *government procurement* (D4). Overall, the U.S. had the most policies and used the broadest range of approaches over the longest period of time.

In terms of conditions, all three countries had policies that combined *decentralized authority* (C2a) and *centralized leadership* (C2b) — possibly reflecting the size of the respective national economies (#1, #2 and #4). The countries also used a mix of solar-specific and *technology neutral* (C3) policies. However, *long-term support* (C1) was the majority of policies only in Germany — which may relate to differences in the political economy, a broader societal support for RE policies, or the specifics of the U.S. (with its reliance on temporary tax credits) or China (with its relatively recent interest in RE).

What was largely or entirely missing from the policies of all three countries?

- *Prizes* (T3): only one prize competition each in the U.S. and China.
- *Pricing externalities* (D3): as was known to MNM, proposals for a "carbon tax" and other such approaches have been proposed but have proven highly controversial.[10]
- *Global cooperation* (C4): was rare in the U.S. and China and non-existent in Germany. We believe that the IEA database accurately reflects each government's tension between economic development and fighting global warming — and thus the general lack of effective global collaboration advocated by MNM — but the data might also omit such collaboration if these policies are enacted through bilateral political negotiations.

In some cases, individual laws combined both push and pull elements, as with the U.S. Solar

[9] In the U.S., subsidized loans to manufacturers were used starting with the 2009 ARRA, but it's too soon to say whether this is an ongoing policy shift or a one-time intervention.

[10] California has announced its own cap-and-trade policy and the European Union has announced an Emissions Tracking Scheme, but both would take effect in 2013.

America Initiative (2006). In other cases, omnibus laws combined a wide range of unrelated policies, as with China's 2007 Climate Change Program or the U.S. American Recovery and Reinvestment Act (2009).

Finally, we found two categories of policies that were not articulated in MNM typology:

- Non-technological "push" policies (i.e. *indirect* technology push): efforts to supply finance, skilled labor or other non-tech supply push factors directly supporting manufacturing appear to be overlooked in the MNM framework.
- Policies improving the interface between supply and demand (i.e. *indirect* demand pull): a central government promoting renewable energy would also want to reduce the likelihood that local circumstances (such as missing infrastructure, building permits or skilled installers) would discourage adoption.

Both the MNM recommendations and the policies enacted in the three countries were distributed across the solar value chain. Most (or in China, nearly all) policies emphasized deployment, i.e. the purchase and installation of solar generating equipment. On the upstream part of the value chain, applied R&D was favored over basic research or manufacturing. Each country also demonstrated increasing policy sophistication over time as the limitations of previous policies became known.

5.2 Policy Outcomes

The IEA database does not include policy outcomes, but from other data we could broadly assess the country-level success of each country's policy efforts — both in ramping up the supply of PV equipment and winning adoption of such equipment to generate electricity.

The U.S. was the early leader in developing PV technology from the 1960s to the 1980s, but adoption was relatively slow due to high prices and inconsistent policy support. In the 21st century, both public and private R&D investment focused on thin film solar technologies (where U.S. firms were deploying new patented technologies), such technologies have been losing global market share since a 2009 peak of 19%, as crystalline silicon cell prices continued their dramatic price cuts (Green, 2005; West, 2011; Wang, 2012).

Meanwhile, Germany's innovative demand pull (feed-in-tariff) policy provided guaranteed funding by electricity customers to assure a predictable rate of return, with spending that totaled €29 billion from 2006-2012. Germany was also distinguished by consistent increases in adoption each year, as compared to other European countries (such as Spain, Czechoslovakia and Italy) that adopted temporary policies that catapulted them into the top ranks of adopters one year, and back to irrelevance later on (Wüstenhagen and Bilharz, 2006; Ren21, 2012; BDEW, 2012).

The Chinese policies were relatively late and (as according to the IEA database) limited in scope. However, through rapid expansion of manufacturing capacity from 2005-2011, China became the world's leading producer of PV equipment: in 2009, First Solar of the U.S. was the first solar manufacturer to ship one gigawatts of capacity in a single year, but by 2011 four Chinese firms had done so. China benefited from country-level spillovers due to demand pull policies in other countries, particularly Germany (Peters et al., 2012). Chinese manufacturers were able to rapidly scale up through financing through government banks in the form of loans, loan guarantees and line of credit, which of course also represents a technology push measure (Edler, Georghiou, 2007). By one estimate, global venture capital in solar totaled $1.7 billion in 2010, but Chinese government banks financed $34 billion in debt that year, including $8.9 billion to LDK Solar from the China Development Bank (Osborne, 2011).[11] Such policies were not reported in the IEA database, and in fact were not openly discussed by the Chinese

[11] The single year investment of $34 billion in 2010 compares to $31.2 billion in combined (depreciated) plant property and equipment for Intel and TSMC, the world's largest semiconductor manufacturers.

government.

Overall, these policies brought global installed capacity of PV equipment to 70 gigawatts at the end of 2011, with Germany accounting for 35% (Ren21, 2012). Fueled by German demand, the rapid growth and scale economies of Chinese manufacturers brought a rapid decline in the cost of PV equipment from 2010-2012 — leading to bankruptcy by PV producers unable to quickly scale up and reduce costs, both in the U.S. (Abound, Evergreen, Solyndra, SpectraWatt) and Germany (Q-Cells, Solon). In response, in 2011 Solar World AG — based in Germany but with U.S. manufacturing operations — filed an unfair trade complaint with the U.S. International Trade Commission, which in 2012 led to U.S. tariffs of up to 36% on Chinese imports.

6. Discussion

This paper answers the call of Mowery, Nelson and Martin (2010) and others in *Research Policy* for an improved understanding of how innovation policy can be used to redirect economic activity to combat manmade global warming. It does so by operationalizing and applying MNM's proscriptions to provide the first in-depth analysis of the national solar policies in three leading markets — U.S., Germany, and China — that extend our understanding of solar industry dynamics and climate change policy more broadly. Finally, it contributes to the literature on the role of technology push and demand pull policies in promoting renewable energy — and innovation adoption more generally — while highlighting the importance of indirect push and pull policies in the adoption of systemic innovations.

6.1 Applying Mowery, Nelson and Martin to the Solar Industry

We developed the first operationalization of the MNM framework by mapping their call into 18 policy principles, and then applied these principles to code 79 solar-related policies from the IEA database from 1974-2011 for the U.S. (the first market for photovoltaic power), Germany (today the largest market) and China (today the largest producer of PV equipment).

The IEA data shows that the most common policy instruments are demand pull, particularly targeted financial incentives (D2) — which are more than twice as common as the most common tech push policies, those for publicly funded R&D (T1a, T1b). Among the MNM conditions, the most common were centralized control (C2b) and technological diversity (C3). Within the value chain, most policies focused on deployment of solar generating equipment.

Actual policies lagged MNM's recommendations (as they were likely aware) in several areas, including broad knowledge dissemination (T2), pricing externalities (D3) and international cooperation (C4). They predicted success would come when "private investments in energy R&D [exceeded] public investments" (Mowery et al., 2010, p.1020) which has been true in the U.S. However, it was not true in Germany (where ratepayer funding through the FiT drove investment) or in China (where government banks funded manufacturing); both Germany and China countries appear to have been more successful than the U.S. on pull or push policies (respectively), consistent with Hargadon and Kenney's (2012) observations about the limitations of private funding for RE investments.

6.2 Challenges of Push and Pull Policies in Renewable Energy

The greenhouse gas reductions from renewable energy come from the installation and use of RE generating equipment. The key driver for adoption of such equipment is stimulating early demand to prime the experience curve and thus create a virtuous cycle of falling prices and increasing adoption (Neij, 1997). Selecting a policy to "prime the pump" of this virtuous cycle intersects the broader debate about the efficacy of technology push and demand pull policies.

Demand pull policies for environmental technologies cause more public benefit through their use (Taylor, 2008) and are more effective in promoting renewable energy (Hargadon, 2010).

However, push policies are often required to promote radical innovation (Abernathy and Clark 1985) while pull policies can bias innovators towards incremental innovation (Nemet, 2009). Nemet (2009) concluded such incrementalism contributed to the limited success of demand policies in promoting adoption of wind power in California from 1975-1991. Consistent with MNM's call for avoiding funding marginal improvements (T1d), many of the U.S. PV R&D investments of the 21st century emphasized major breakthroughs, particularly in thin film PV.

When compared to Nemet, our study of solar across three countries suggests that solar adoption was driven not by dramatic radical breakthroughs, but through the accumulated incremental improvements from 1974-2011. For manufactured components such as solar panels, efforts to stimulate demand — particularly the German feed-in-tariff — grew the market, allowed for learning and scale effects, attracted new entry and led to relentless cost pressures — not only in Germany, but due to country-level spillovers also in China and the U.S. (Peters et al., 2012). The result of demand stimulation was a steady cost reduction in panel costs over 30 years — a 22% cost reduction for every doubling of the industry's cumulative panel production (IRENA, 2012). Meanwhile, this market growth and competition incentivized decentralized cost reduction in the "Balance of System" (non-solar panel components) as suppliers and installers addressed each "reverse salient" of cost barriers as they arose (cf. Hughes, 1989). Non-standard solar technologies (such as Solyndra's thin film tubes) were unable to benefit from this cost reduction.

While such incremental improvements cut panel prices more than ten-fold over three decades, the private investments necessary to achieve scale economies required a long-term consistency that was notably present in the German policies and lacking in key U.S. ones (China's RE policies being too recent to provide a clear picture) (see also Lüthi, 2010). The predictability of FiT returns also overcame a key uncertainty deterring RE investment — weighing the long-term price of traditional energy against known short-term RE capital costs (cf, Jaffe et al., 2002).

The policies of these three countries also highlight the importance of indirect measures supporting technology push and demand pull. On the push side, new technologies cannot make it into practice unless they are produced, which turns out to be a crucial bottleneck for a high-volume price-sensitive market such as energy; all three countries provided support to help domestic manufacturing (and thus domestic job growth) though at different point of times and with different amplitude. On the pull side, the interface between manufacturers and eventual buyers can help or hurt the adoption process: for solar panels, key issues include local government regulation, distribution, skilled installers and financing. Such interface improvements increase the rate of adoption of solar equipment in a given economy, but not necessarily sales of domestic producers.

6.3 Role of Infrastructure and Other Assets in Innovation Adoption

Beyond traditional technology push and buyer pull, Taylor (2008) identified the importance of improving the interface between producers and buyers. Improvements to such interfaces — which remove barriers to adoption by buyers and thus stimulate buyer demand — accounted for nearly a third of U.S. policies in our study (more in China, less in Germany).

Such interface improvements — whether reducing regulatory barriers to adoption or increasing availability of skilled installation staff — apply beyond the solar industry of our study (and Taylor's) to broader challenges of distributed production of renewable energy. This suggests links to two earlier literatures — the role of infrastructure in adoption of systemic innovation, and the producer's need to attract both end-users and co-specialized complementary assets such as installers.

Systemic innovation requires the careful coordination of many design, production and deployment decisions to make sure that the various elements of the system are available simultaneously, and are subject to a wide range of unanticipated or unintentional interactions (Bergek et al, 2008). A common requirement for adoption of such innovations is the deployment of an infrastructure that enables adoption of the end technology (Hargadon and Douglas, 2001; Maula et al 2006). Examples of such infrastructure might include not only installers for distributed solar power systems, but charging/fueling stations for electric or hydrogen cars (MacKenzie, 1994).

This corresponds to the more general problem of attracting a supply of specialized complementary assets (Teece, 1986) — which both require and are required by adoption of the end product — whether installers and solar panels or (as in Anderson and Parker, 2013) storage to supplement intermittent RE power generation. The producers thus face the challenge of attracting both parties of a two-sided market (cf. Evans, 2003) — in this case, both infrastructure (installers) and buyers of the end product (panels). As with any such two-sided market, producers must either attract third-party investment to create such infrastructure in anticipation of buyers, or fund the creation of such infrastructure themselves. Although this would increase capital requirements, a few firms (such as the largest US producer, First Solar) developed such end-to-end integration to assure the availability of such assets and reduce obstacles to deployment.

6.4 Limitations and Future Research

Our sample had important limitations. We didn't measure subnational policies for U.S. or German states, nor supranational policies (e.g., the EU). While providing commensurable data across three countries, inferences about policy prevalence (particularly for China) are based on small numbers. Due to incomplete data, we can't measure the financial magnitude of all the policies and (beyond adoption) lack outcome measures for their respective efficacy.

As MNM note, the challenges of transforming national energy policies to address global warming are daunting. Future research might extend the application of MNM's recommendations (and this coding scheme) to other renewable energy technologies in other geographic contexts. It might also examine some of the desirable but rare aspects of their recommendations, particularly global cooperation which as MNM (and Peters et al., 2012) note, is essential to link national jurisdictions to address a global environmental challenge. Meanwhile, the context of renewable energy adoption offers a series of large-scale quasi-experiments to consider the relative contribution of push and pull policies — not only the direct effects previously theorized, but indirect factors that link technology supply to user demand.

Finally, of particular interest to *Research Policy* readers, there is a dearth of empirical and theoretical literature on the diffusion and adoption of systemic innovations. While researchers have examined telecommunications, digital networks, energy and banking, a broader perspective (building on that for complementary assets and two-sided markets) is needed to explain the more general processes of creating and promoting adoption for a complex system. While general economic (e.g. Antonelli, 2001) and sociotechnical (Lyytinen and Newman, 2008) models of systemic innovation have been proposed, they have not been linked to empirical studies of how actual systems are conceptualized, designed, developed, produced and adopted.

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8. Tables and Figures

Country	Total RE Polices*	Relevant RE Policies†	Earliest Relevant RE Policy
U.S.	100	49	1974
Germany	41	17	1990
China	34	13	1996
Total	*175*	*79*	-

* All renewable energy policies in IEA database announced on or before December 2011.
† Includes all national policies that either are PV-specific policies, or are RE policies which include PV.

Table 1: Relevant policies from IEA database. 1974-2011

Group	Code	Policy design principle	Description and rationale
Technology push	*T*	*Funding technological research, development, and demonstration*	
	T1a	Public institutions performing publicly funded R&D	Public research institutions are important especially in basic research and in defining future research directions.
	T1b	Industry performing publicly funded R&D	Industrial firms are important in performing publicly funded R&D.
	T1c	Private investment in R&D	Funding should shift from public to private.
	T1d	No public funding of marginal improvement	Public spending should not support incremental improvements of existing technologies and instead focus on the technological frontiers.
	T2	Broad research availability	The result from publicly funded R&D should be broadly disseminated, and patents for upstream technologies discouraged or licensed at low cost.
	T3	Technology contests	Stimulate R&D efforts via rewarding technological achievements through prizes.
	T4	Technology demonstration	To demonstrate the feasibility of new technological designs R&D programs can include demonstration projects for early trial use.
	T5	Learning in use	Policies which connect adopters of technologies with manufacturers and R&D organizations to facilitate feedback of operating experience into the R&D process.
Demand pull	*D*	*Catalyze technological innovation by stimulating demand*	
	D1	Regulatory performance targets	Policies should drive demand towards alternative technologies through regulated performance targets.
	D2	Targeted financial incentives	Financial and fiscal instruments can be applied to encourage certain behavior, such as investments leading to early adopter or increased market demand.
	D3	Pricing emissions externalities	Policies should correct market prices for existing technologies (e.g., coal based power production) which do not reflect full social costs.
	D4	Government procurement	The diffusion of alternative energy technologies can be spurred by government procurement policies.
	D5	Public dissemination programs	Public information and dissemination programs to facilitate networking amongst various actors, such as (prospective) users and producers in order to spur adoption.
Conditions	*C*	*Characteristics of either supply or demand policies*	
	C1	Long-term support	A long-term perspective and stable and credible policy commitments (5+ years) are necessary for developing and improving alternative technologies and their adoption.
	C2a	Decentralized programs	Decentralization of policy programs spans diverse instances responsible for technology priority-setting, funding, and performance control.
	C2b	Centralized leadership	A centralized administrative structure sets overall priorities, monitors progress and evaluates performance.
	C3	Technological diversity	The energy-related technologies that are involved in any solution to global warming are extraordinarily diverse and will be developed and produced by firms in many different industrial sectors.
	C4	Global cooperation	Alternative energy technologies address a global problem but are applied locally; co-operation of national governments and even international subsidies are necessary to work on this global-local challenge.

See Appendix A.1 for coding rules and more detailed explanations of each category.

Table 2: Coding push vs. pull policy proscriptions of Mowery, Nelson and Martin (2010)

Value chain stage	Targeted actors	Types of policies	PV-related examples
Basic research	Science partners	Policies directed at encouraging basic research; often funding is provided for public research laboratories.	• New chemical formulas for solar cells
Applied R&D	Science partners, Industry	Policies funding research and development projects both for advancing technology and related manufacturing processes.	• More efficient solar panel/system
Manufacturing	Industry	Policies (which are not R&D) supporting competitive manufacturing and up-scaling.	• Subsidies for scaling up solar manufacturing • Provision of free solar workforce training
Interface improvement	Local government regulators, utilities, architects, installers	Policies for creating conditions and infrastructure that enable the subsequent deployment and use of technology.	• Providing regulatory basis (e.g. grid access) • Development of building codes for integrating solar technology • Streamlining permission/inspection procedures • Declaration of possible sites • Installer training
Deployment	Buyers of PV equipment	Policies incentivizing deployment of new technologies through financial incentives (grants, tax reductions, subsidized loans), technical assistance or education and outreach.	• Grants for procurement of solar panels • Feed-in-tariff for production of solar electricity
Use	End-users of electricity	As with deployment, encourages use of solar equipment, but focuses on end-users and applications in which technology is embedded or technology-related outputs are used.	• Diffusion of green power contracts which increase the use of green electricity
Demonstration	Science partners, industry, utilities, lead users	Polices facilitating the demonstration of the feasibility of new technological designs. Demonstration projects in this category focus on pre-commercial designs (e.g. demonstration plants, field trials, prototype development) for early trial use, rather than commercial demonstration projects used to encourage deployment.	• First time large-scale installation of new PV module (e.g. by a utility)

Table 3: Mapping policies to phases of the value chain

Codes			U.S.		Germany		China		All		
Group	**Code**	**Policy**	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	**Mean[1]**
Technology push	T1a	Publicly funded public R&D	11	22%	4	24%	5	38%	20	25%	28.1%
	T1b	Publicly funded private R&D	11	22%	3	18%	5	38%	19	24%	26.2%
	T1c	Private investment in R&D	6	12%	3	18%	0	0%	9	11%	10.0%
	T1d	No public funding of marginal improvement	4	8%	0	0%	0	0%	4	5%	2.7%
	T2	Broad knowledge dissemination	0	0%	3	18%	3	23%	6	8%	13.6%
	T3	Prize competition	1	2%	0	0%	1	8%	2	3%	3.2%
	T4	Demonstration projects	9	18%	3	18%	0	0%	12	15%	12.0%
	T5	Learning in use	0	0%	4	24%	0	0%	4	5%	7.8%
Demand pull	D1	Regulatory performance targets	1	2%	6	35%	6	46%	13	16%	27.8%
	D2	Targeted financial incentives	17	35%	12	71%	9	69%	38	48%	58.2%
	D3	Pricing externalities	1	2%	0	0%	2	15%	3	4%	5.8%
	D4	Government procurement	9	18%	1	6%	0	0%	10	13%	8.1%
	D5	Public dissemination programs	15	31%	2	12%	3	23%	20	25%	21.8%
Conditions	C1	Long-term support	18	37%	13	76%	5	38%	36	46%	50.6%
	C2a	Decentralized authority	18	37%	6	35%	9	69%	33	42%	47.1%
	C2b	Centralized leadership	47	96%	13	76%	9	69%	69	87%	80.5%
	C3	Technological diversity	37	76%	12	71%	7	54%	56	71%	66.6%
	C4	International cooperation	3	6%	0	0%	3	23%	6	8%	9.7%
Value chain	Basic	Basic research	4	8%	3	18%	2	15%	9	11%	13.7%
	R&D	Research and development	10	20%	4	24%	4	31%	18	23%	24.9%
	Manu-facturing	Manufacturing	6	12%	0	0%	2	15%	8	10%	9.2%
	Demo	Demonstration	11	22%	4	24%	1	8%	16	20%	17.9%
	Interface	Interface improvement	15	31%	3	18%	5	38%	23	29%	28.9%
	Deploy	Deployment	29	59%	11	65%	12	92%	52	66%	72.1%
	Use	Use	7	14%	2	12%	4	31%	13	16%	18.9%
Push vs. Pull		Push only	11	22%	3	18%	1	8%	15	19%	15.9%
		Pull only	31	63%	13	76%	7	54%	51	65%	64.5%
		Both push and pull	7	14%	1	6%	5	38%	13	16%	19.5%
		Total	49		17		13		79		

Table 4: Descriptive coding statistics of three country samples

[1] The unweighted mean of the three country ratios.

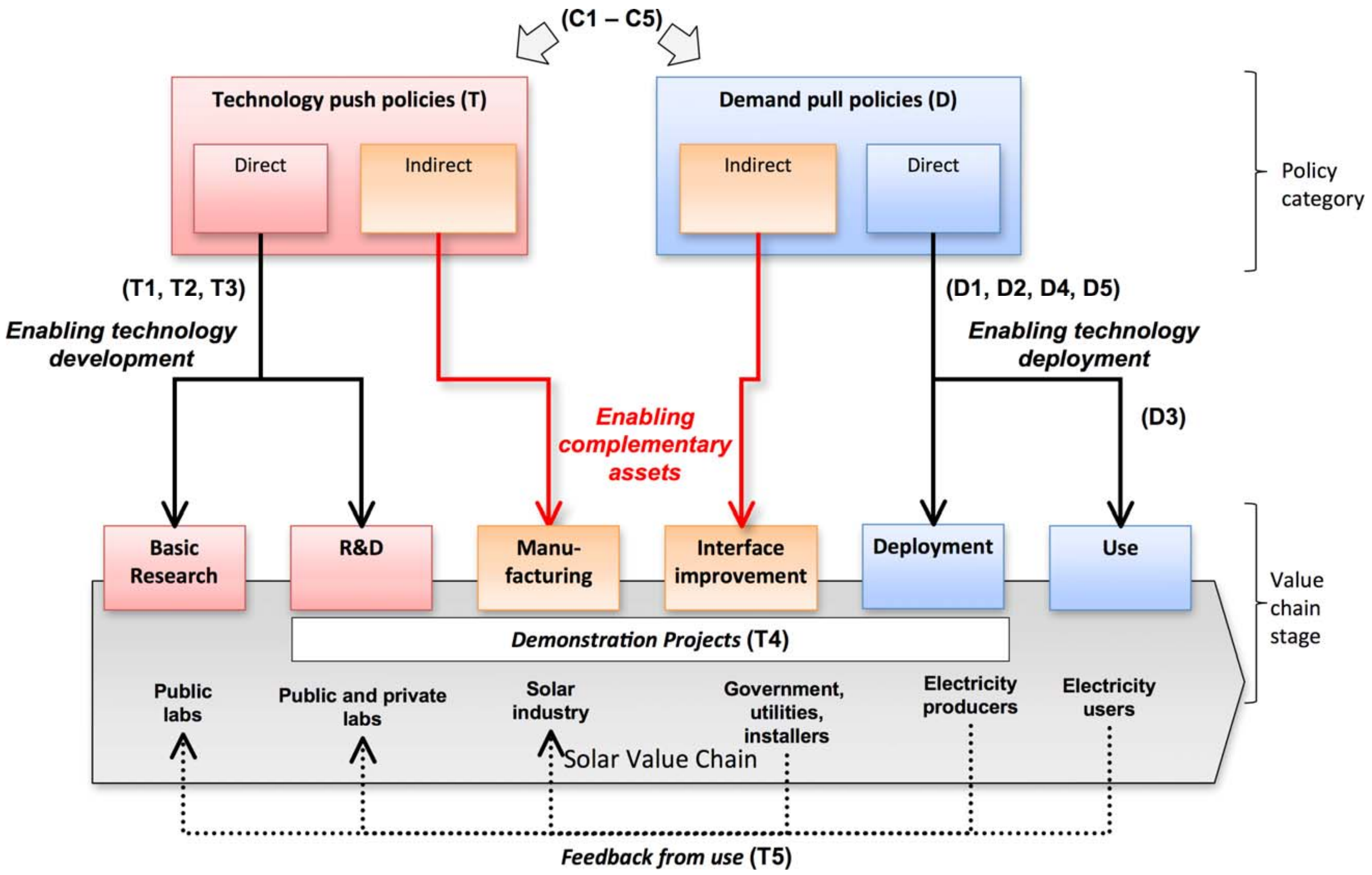

Figure 1: Solar value chain

Appendix A

Intended for online publication

Code	Policy design principle	Description and rationale	Exemplary statements from MNM	Qualitative indicators (proxies)
T	*TECHNOLOGY PUSH: Funding technological research, development, and demonstration*			
T1a	*Public institutions performing publicly funded R&D*	Public research institutions are important especially in basic research and in defining future research directions.	Note: This principle results from MNM's statements on research performed by industry (see T1b). In consequence, even if the share of industrial research increases, public institutions performing (basic) R&D remain.	Public budgets allocated to universities or public research institutions; e.g., to researchers at national or local agencies, competence centers (e.g., German Helmholtz Centers, U.S. National Research Laboratories)
T1b	*Industry performing publicly funded R&D*	Industrial firms are important in performing publicly funded R&D.	"… a significant portion of government R&D funding for the development of climate-friendly energy technologies is likely to support R&D performed by industrial firms. Industry will play an especially important role as a performer of publicly funded R&D in prototype development and testing." (p. 1020)	Public budgets allocated to private research; e.g., funding corporate R&D, private research centers, industrial technology clusters
T1c	*Private investment in R&D*	Funding should shift from public to private.	"… public R&D investments in the development of new energy technologies must be complemented by private investments in energy R&D; indeed, if the initiative is to be successful, private investments in energy R&D are likely to exceed public investments." (p. 1020)	Public funding stimulates or even obliges private spending for R&D; e.g., through matching schemes
T1d	*No public funding of marginal improvement*	Public spending should not support incremental improvements of existing technologies and instead focus on the technological frontiers.	"… established firms or user groups are able to exert a dominant influence over the agenda of public R&D programs … [and] are likely to focus on near-term improvements in existing technologies. [But] public funding for marginal improvements of existing technologies is misdirected. Instead, public support should focus on advancing the technological frontiers." (p. 1021)	1.) Policy supports basic research and "big leaps" with an obvious distance to commercialization *or* 2.) Policy does not support technologies on the market or nearly ready for the market
T2	*Broad research availability*	The result from publicly funded R&D should be broadly disseminated, and patents for upstream technologies should be discouraged or licensed at low cost.	"[S]ocial returns to R&D … are likely to be greater when those results are broadly available… [G]overnments [should] structure their R&D programs to support and encourage broad dissemination of the scientific and technological knowledge produced by their R&D investments … [P]atenting should be reserved for results that are close to practical application and that patenting of research results whose use is primarily as an input to further research should be minimized."(p. 1020)	1.) Existence of measures to require or enable dissemination of public or private R&D results; e.g., through dedicated communication infrastructure, funding for dissemination *or* 2.) Patenting rules must avoid exclusivity in case of basic R&D results or discourage exclusive patent licensing in case of basic R&D results
T3	*Technology contests*	Stimulate R&D efforts by means of rewarding technological achievements through prizes.	"Prizes … have been recommended as a complement to other instruments of government policy, including public R&D funding, in supporting the development of climate-friendly energy technologies. Prizes are best-suited to the 'technological breakthrough' characterization of innovation …" (p. 1021)	Existence of publicly initiated contests for technological achievements; criteria are e.g. newness, breakthrough potential; prizes can be awards, contracts; achievements may cover both technological breakthrough as well as broader systems development

Code	Policy design principle	Description and rationale	Exemplary statements from MNM	Qualitative indicators (proxies)
T4	*Technology demonstra-tion*	To demonstrate the feasibility of new technological designs R&D programs can include demonstration projects for early trial use.	"Demonstration projects provide a bridge between R&D and use of a technology in the environment of actual practice … As such, demonstration projects can provide important information for future R&D investment … We believe that effective public programs … should also include mechanisms for the support and encouragement of early trial use of new technologies …" (p. 1021)	Support of prototype development and demonstration aiming at early trial use experiences; e.g., demonstration plants, field trials, prototype development
T5	*Learning in use*	Policies which connect adopters of technologies with manufacturers and R&D organizations in order to facilitate feedback of operating experience into the R&D process.	"… learning in use also means that broader adoption and more extensive operating experience will feed back into improvements in these alternative-energy technologies … These closely linked processes of adoption and technological improvement may benefit from public information dissemination programs that link early adopters with one another and with major producers and R&D …" (p. 1013)	Existence of dissemination mechanisms that facilitate exchange between adopters/users with manufacturers and/or R&D organizations
D	*DEMAND PULL: Catalyze technological innovation by stimulating initial and increased demand*			
D1	*Regulatory performance targets*	Policies should drive demand towards alternative technologies through regulated performance targets.	"Specific regulatory requirements (e.g. emission or performance targets) or targeted financial incentives (tax credits), may spur the adoption of specific technologies … Supportive price and regulatory policies can significantly enhance the effectiveness of government R&D programs in this area." (p. 1020)	1.) Existence of national (state- or other level) performance targets; e.g., in terms of renewable energy production or CO_2-reductions *or* 2.) Existence of targets either on the technology or the user level; e.g., quotas of renewable energy usage, CO_2 emissions, but also performance in terms of technology costs
D2	*Targeted financial incentives*	Financial and fiscal instruments can be applied to encourage certain behavior, such as investments, that leads to early adopter or increased market demand.	"… the early versions of most alternative energy technologies would be handicapped in direct comparisons with existing technologies … the adoption of the initial versions of more environmentally friendly technologies may require subsidies or other forms of public support for early adopters of these technologies." (p. 1013)	Existence of financial (e.g. preferential loans, direct payments) and fiscal (e.g. reduced taxes) instruments aiming at early adopters or the stabilization of given demand; common examples are feed-in-tariffs, rebates, preferential loans, or tax incentives
D3	*Pricing emissions externalities*	Policies should correct market prices for existing technologies (e.g., coal based power production) which do not reflect full social costs.	"Any policy to address global warming must address this failure of prices to accurately reflect social costs, for example, through a tax on carbon or a 'cap and trade' system of emissions targets." (p. 1013)	Existence of mechanisms that modify market prices of fossil fuels and other conventional technologies to reflect negative externalities; e.g., taxes on competing technologies, carbon taxes, emission trading schemes
D4	*Government procurement*	The diffusion of alternative energy technologies can be spurred by government procurement policies.	"Government will be an important user of some of the new energy technologies, and public procurement policies can be used to promote certain technologies or applications … governments might be better advised to use procurement competitions to encourage the development of climate-friendly energy technologies that could be implemented in public applications." (pp. 1020, 1021)	Existence of public procurement or investment programs aiming at public users buying alternative energy technologies, or energy
D5	*Public diss-emination programs*	Public information and dissemination programs to facilitate networking amongst various actors, such as (prospective) users and producers in order to spur adoption.	"These closely linked processes of adoption and technological improvement may benefit from public information dissemination programs that link early adopters with one another and with major producers and R&D organizations." (p. 1013)	Existence of dissemination mechanisms that link existent (and prospective) users with each other to share in-use experiences; this covers, e.g., education and training of (potential) adopters, public events, websites and related mechanisms

Code	Policy design principle	Description and rationale	Exemplary statements from MNM	Qualitative indicators (proxies)
C	*CONDITIONS: Conditions or characteristics to either supply or demand policies*			
C1	*Long-term support*	A long-term perspective and stable and credible policy commitments are necessary for developing and improving alternative technologies and their adoption.	"… public programs should focus on long-term support for the development and improvement of relevant technologies, rather than seeking a one-time technological breakthrough … Stability and credibility are therefore important goals for the design of energy R&D programs, as well as for the demand-side policies …" (pp. 1020, 1022)	The basic policy principle (e.g. research funding, feed-in system, government procurement, tax incentives) was at least five years in effect (without threat to be discontinued in between) and received relatively continuous funding during that timeframe
C2a	*Decentralized programs*	Decentralization of policy programs spans diverse instances responsible for technology priority-setting, funding, and performance control.	"A considerable amount of decentralization is desirable or even essential in an energy R&D program that spans such a diverse array of technologies, industries, countries, users, and applications, and which involves such a wide range of activities." (p. 1021)	Existence of more than one instance that prioritizes, funds, and controls for technology performance; e.g. different government agencies in charge of policy definition or execution
C2b	*Centralized leadership*	A centralized administrative structure sets overall priorities, monitors progress and evaluates performance.	"… a centralized administrative structure for setting broad priorities, monitoring overall progress, and evaluating performance is a necessary complement to a decentralized program structure." (p. 1021)	Existence of one central authority (regardless on which level, local, state, or national) that defines overall policy goals, monitors, and evaluates goal achievement; e.g. a single federal agency that is responsible for the policy strategy definition and execution
C3	*Technological diversity*	The energy-related technologies that are involved in any solution to global warming are extraordinarily diverse and will be developed and produced by firms in many different industrial sectors.	"An effective R&D program to combat climate change must support the development and deployment of many different technologies that will be employed in a diverse array of sectors …" (p. 1019)	Coverage of additional renewable energy technologies besides solar
C4	*Global cooperation*	Alternative energy technologies address a global problem but are applied locally; co-operation of national governments and even international subsidies are necessary to work on this global-local challenge.	"… it is critically important to work out an appropriate division of labor among national governments and to create effective mechanisms for cooperation and coordination. Much more than 'technology transfer' will be required, although support for the global dissemination of information and, potentially, subsidies for other nations …" (p. 1022)	1.) National actors that co-operate across borders *or* 2.) Definition of goals that affect more than one country *or* 3.) Transfers of money, knowledge, work force etc. between countries

Table A.1: Coding push vs. pull policy proscriptions of Mowery, Nelson and Martin (2010)

PV-related policies in the U.S.			**Technology push**								**Demand pull**					**Conditions**					**Solar Value Chain**					
Policy	***Year***	***Policy Instrument***	**T1a**	**T1b**	**T1c**	**T1d**	**T2**	**T3**	**T4**	**T5**	**D1**	**D2**	**D3**	**D4**	**D5**	**C1**	**C2a**	**C2b**	**C3**	**C4**	**Basic**	**R&D**	**Manufact.**	**Demo.**	**Interface**	**Deploy**	**Use**
Solar Photovoltaic Energy Research, Development and Demonstration Act	(1974-1978) 1978-2009	R&D funding	+	+					+							+		+		+	+	+		+		+	
Public Utility Regulatory Policies Act (PURPA)	1978-present	Regulatory instrument (mandate)														+		+	+						+		
Energy Tax Act of 1978 (including Tax Reform Act of 1986)	***1978-1992***	***Package***																									
Residential Energy Tax Credit	1978-1985	Incentives (tax credit)										+						+	+							+	
Business Energy Tax Credits	1978-1992	Incentives (tax credit)										+						+	+							+	
(Modified) Accelerated Cost Recovery System (MACRS)	1981-1986 1986-present	Incentives (tax credit)										+				+		+	+							+	
Renewable Portfolio Standard (RPS)	1983-present	Regulatory instrument (mandate)									+					+	+		+							+[1]	
Energy Policy Act (EPAct) 1992, EPAct 2005	***1992-present 2005-present***	***Package***																									
Federal Business Investment Tax Credit (ITC)	1992-2005 2005-2016	Incentives (tax credit)										+				+		+	+							+	
Production Tax Credit (PTC)	1992-2003 (no solar) 2004-2005 (w/ solar) 2005-present (no solar)	Incentives (tax credit)										+						+	+							+[1]	
Renewable Energy Production Incentive (REPI)	1992-2005 2005-2026	Incentives (tax credit)										+						+	+							+[1]	
Tribal Energy Program	1994-present	Education/outreach, incentives (grants), financial (funds to sub-national governments)							(+)			+			+	+	+	+	+					+	+	+	
Photovoltaic Energy Commercialization Program	2005-present	Government procurement								(+)		+		+			+	+								+	
Loan Guarantee Program (for Innovative Energy Technologies)	2007-present	Incentives (preferential loans)										+						+	+				+	+		+	
Residential Renewable Energy Tax Credit	2006-*2016*	Incentives (tax credit)										+						+	+							+	
(New) Clean Renewable Energy Bonds (CREB)	2005-present 2009-2010 (New)	Incentives (preferential loan)										+						+	+							+	
Federal Utility Partnership Working Group (FUPWG)	1994-present	Education/outreach													+	+		+	+				+	+			
State Energy Program	1996-present	Incentives (tax credit, preferential loans), education/outreach										+			+	+	+	+	+						+	+	
E.O. 13123 ("Greening the Government Through Efficient Energy Management")	1999-2007	Policy process (institutionalization), government procurement												+		+	+	+	+							+	+
Greening of the National Park Service	1999-present	Education/outreach, government procurement												+	+			+	+							+	

PV-related policies in the U.S.			**Technology push**								**Demand pull**					**Conditions**					**Solar Value Chain**						
Policy	***Year***	***Policy Instrument***	**T1a**	**T1b**	**T1c**	**T1d**	**T2**	**T3**	**T4**	**T5**	**D1**	**D2**	**D3**	**D4**	**D5**	**C1**	**C2a**	**C2b**	**C3**	**C4**	**Basic**	**R&D**	**Manufact.**	**Demo.**	**Interface**	**Deploy**	**Use**
Energy Efficiency and Renewable Energy (EERE) International Activities	1999-present	Education/outreach, R&D funding	+	+	+										+	+		+	+	+		+			+		
Green Power Partnership	2001-present	Voluntary agreement, education/outreach												(+)	+	+		+	+								+
Solar Decathlon	2002-present	Education/outreach, demonstration projects,						(+)	+						+	+		+						+	+	(+)	
Rural Energy for America Program (REAP) Grants	2002-2008 2008-present	Incentives (grants; preferential loans)										+				+	+	+	+							+	
Interconnection Standards for Small Generators	2005-present	Regulatory instrument														+		+	+						+		
State and Local Climate and Energy Program	**2005-present**	***Package***																									
State Climate and Energy Program	2005-present	Education/outreach, policy process													+	+	+	+	+						+	+	+
State Climate and Energy Partner Network (previously: EPA's Clean Energy–Environment State Partnership)	(2005-2009) 2009-present	Education/outreach, policy process													+		+	+	+						+	+	+
State Utility Commission Assistance	2005-present	Education/outreach													+		+	+	+						+	+	+
Climate Showcase Communities Grant	2009-present	Education/outreach							+						+		+	+	+					+		+	
Solar America Initiative (SAI)	***2006-2009***	***Package***																									
Solar America Board for Codes and Standards	2007-2009	Education/outreach, regulatory instrument (codes/standards)													+			+							+		
Solar America Cities	2007-2009	Financial (funds to sub-national governments), education/outreach										+		+	+		+	+							+	+	
Solar America Showcases	2007-2009	Education/outreach													+			+								+	
Solar America Future Generation PV	2007-2009	R&D funding	+	+		+												+			+	+					
Solar America PV Incubator	2007-2009	R&D funding	+	+		+			+									+				+		+			
Solar America Technology Pathway Partnerships	2007-2009	R&D funding	+	+	+				+									+				+	+	+			
Solar America University PV Product and Process Development	2007-2009	R&D funding	+	+	+													+				+					
Technology Commercialization Fund (TCF)	2007-2008	Incentives (grants), demonstration projects			+				+			+					+	+	+			+		+			
Energy Independency & Security Act (EISA) of 2007	***2007-present***	***Package***																									
Solar Energy Research and Advancement Act	2007-present	R&D funding	+	+	+				+								+	+				+		+	+	(+)	
Energy Efficiency and Conservation Block Grants	2007-present	Incentives (subsidies)										+		+			+	+	+						+	+	
Renewable Energy Innovation Manufacturing Partnership Program	2007-present	R&D funding	+	+					+							+		+	+			+	+	+			

PV-related policies in the U.S.			**Technology push**								**Demand pull**					**Conditions**					**Solar Value Chain**						
Policy	***Year***	***Policy Instrument***	**T1a**	**T1b**	**T1c**	**T1d**	**T2**	**T3**	**T4**	**T5**	**D1**	**D2**	**D3**	**D4**	**D5**	**C1**	**C2a**	**C2b**	**C3**	**C4**	**Basic**	**R&D**	**Manufact.**	**Demo.**	**Interface**	**Deploy**	**Use**
Green Jobs Act (based on Workforce Investment Act (WIA) of 1998)	2009-present	Education/outreach															+	+	+				+		+		
International Energy Programs	2007-present	Education/outreach													+					+						+	
E.O. 13432 (“Strengthening Federal Environmental, Energy, and Transportation Management”)	2007-present	Policy process (institutionalization), government procurement												+		+	+	+	+								+
Advanced Research Projects Agency—Energy (ARPA-E)	2007-present	Research program	+	+	+	+												+	+		+	+					
National Defense Authorization Act	2008-2009	Government procurement, education/outreach	+	+										+				+	+							+	
Western Renewable Energy Zones (WREZ) Project	2008-present	Policy process															+	+	+						+		
Energy Improvement and Extension Act 2008	2008-present	Incentives (tax, tax credit)										+	+					+	+							+	
E.O. 13514 (“Federal leadership in Environmental, Energy, and Economic Performance”)	2009-present	Policy process (institutionalization), government procurement												+		(+)	+	+	+							+	+
American Recovery and Reinvestment Act (ARRA)	***2009***	***Package***																									
Renewable Energy Grants Program	2009-2011	Incentives (grants)										+						+	+							+	
Energy Frontier Research Centers (EFRCs)	2009-2013	Research program	+	+		+												+	+		+						
Advanced Energy Credit for Manufacturers	2009-present	Incentives (tax credits)																+	+				+				

[1] Relates to incentives for production of electricity (instead of mere installation of energy technology)
+ = clearly identified; (+) = partly identified; a, b, c, d = identified subcodes (e.g. ‘a’ = T1a; ‘b’=T1b)

Table A.2: PV-related policies in the United States, 1974-2009

PV-related policies in Germany			Technology push								Demand pull					Conditions					Solar Value Chain						
Policy	***Year***	***Policy Instrument***	**T1a**	**T1b**	**T1c**	**T1d**	**T2**	**T3**	**T4**	**T5**	**D1**	**D2**	**D3**	**D4**	**D5**	**C1**	**C2a**	**C2b**	**C3**	**C4**	**Basic**	**R&D**	**Manufact.**	**Demo.**	**Interface**	**Deploy**	**Use**
1,000 Roofs Solar Power Program	1990-1995	Incentives (grants), Education/outreach (information dissemination), R&D funding	+							+		+			+		+	+				+		+		+	
KfW Environment and Energy Saving Program (ERP)	1990-2008	Incentives (preferential loans)										+				+		+	+							+	
Electricity Feed-In Law (StromEinspG)	1991-2000	Incentives (feed-in tariffs), regulatory instrument									+	+				+		+	+							+[1]	
Full Cost Rates	1993-2000	Incentives (feed-in tariff)									+	+				+	+									+[1]	
100 Million Program	1995-1998	Education/outreach (promotion), incentives (grants)										+						+	+							+	
Ordinance on the Fee Schedule for Architects and Engineers	1995-present	Regulatory instrument (codes/standards)									+	+				+		+	+						+		
Green Power	1996-present	Incentives (feed-in tariff) (government procurement)										+		(+)		+	+		+							+[1]	(+)
Federal Building Codes for Renewable Energy Production	1997-present	Regulatory instrument (codes/standards)									+					+		+	+						+		
Energy Industry Act	1998-present	Regulatory instrument									+					+		+	+						+		
100,000 Roofs Solar Power Program	1999-2003	Incentives (preferential loans)										+						+								+	
Renewable Energy Sources Act (EEG)	2000-present	Incentives (feed-in tariffs), regulatory instrument									+	+				+		+	+							+[1]	+
KfW Program Producing Solar Power	2005-2008	Incentives (preferential loans)										+						+								+	
5th Energy Research Program	2005-2010	R&D funding, research program	+	+	+		+		+	+						(+)	+		+		+	+		+			
Photovoltaic Technology Evaluation Center (PV-Tec) at Fraunhofer ISE	2006-present	R&D funding, voluntary agreement	+	+	+		+		+	+						+	+	+			+	+		+			
Climate Protection Investment from Sale of Carbon Allowances	2008-present	Incentives (grants)										+			(+)	+		+	+							+	
KfW Renewable Energies Program	2009-present	Incentives (preferential loans)										+				+		+	+							+	
6th Energy Research Program	2011-present	R&D funding, research program	+	+	+		+		+	+						(+)	+		+		+	+		+			

[1] Relates to incentives for production of electricity (instead of mere installation of energy technology)
+ = clearly identified; (+) = partly identified; a, b, c, d = identified subcodes (e.g. 'a' = T1a; 'b'=T1b)

Table A.3: PV-related policies in Germany, 1990-2011

PV-related policies in China			**Technology push**								**Demand pull**					**Conditions**					**Solar Value Chain**						
Policy	***Year***	***Policy Instrument***	**T1a**	**T1b**	**T1c**	**T1d**	**T2**	**T3**	**T4**	**T5**	**D1**	**D2**	**D3**	**D4**	**D5**	**C1**	**C2a**	**C2b**	**C3**	**C4**	**Basic**	**R&D**	**Manufact.**	**Demo.**	**Interface**	**Deploy**	**Use**
Brightness Program	1996 - present	Policy process (strategic planning)									+				+	+	+	+								+	+
Preferential Tax Policies for Renewable Energy	2003-present	Incentives (taxes, tax incentives)										+							+	+			+			+	
Renewable Energy Development Targets	2006	Policy process (strategic planning)									+							+	+							+	
Renewable Energy Law	2006-2009	Policy process (strategic planning)	+	+			+				+	+				+	+	+	+			+			+	+	+
Medium and Long Term Development Plan for Renewable Energy	2007-present	Policy process (strategic planning)	+	+							+	+				+	+	+						+	+	+	
National Climate Change Program	2007-present	Policy process (strategic planning)	+	+			+				+		+			+		+	+	+	+	+	+		+	+	+
International Science and Technology Cooperation Programme for New and Renewable Energy	2008-present	Education/outreach (information dissemination), R&D funding	+	+				+											+	+	+	+					
Renewable Energy Law amendments	2009-present	Policy process (institutionalization), public investment (infrastructure), R&D funding	+	+			+				+	+	+			+	+	+	+			+			+	+	+
Golden Sun Programme	2009-present	Incentives (grants)										+			+		+	+							+	+	
Renewable Electricity Premium (surcharge)	2009-present	Incentives (feed-in tariffs)										+					+	+	+							+	
Building Integrated Solar PV Programme	2010-present	Incentives (grants)										+					+									+	
Interim Feed-in Tariff for Four Ningxia Solar Projects	2010-present	Incentives (feed-in tariffs)										+			+		+									+	
Solar PV feed-in tariff	2011-present	Incentives (feed-in tariffs)										+					+	+								+	

[1] Relates to incentives for production of electricity (instead of mere installation of energy technology)
+ = clearly identified; (+) = partly identified; a, b, c, d = identified subcodes (e.g. 'a' = T1a; 'b'=T1b)

Table A.4: PV-related policies in China, 1996-2011

VI. Lüdeke-Freund, F. & Loock, M. (2011): Debt for brands: Tracking down a bias in financing photovoltaic projects in Germany, Journal of Cleaner Production, Vol. 19, No. 12, 1356-1364.

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Debt for brands: tracking down a bias in financing photovoltaic projects in Germany☆

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ABSTRACT

What kinds of PV project configurations do lenders prefer to finance? Recent developments in the field of renewable energy project finance have reinforced the need for investigation, as fundraising has become more challenging and project evaluation by banks more demanding. To contribute to the limited research in this field, we focus on photovoltaic projects and report from an Adaptive Choice-Based Conjoint experiment with German experts in project finance. We find a bias which we call "debt for brands". Simulations reveal that debt investors prefer projects with premium brand technology (modules, inverters) to low-cost technology. Although we assumed that lenders prefer projects with the highest Debt Service Cover Ratio (DSCR), they favor projects with lower DSCR, as long as those projects include premium brand technology. We find that, if premium brands were engaged, lenders would also choose projects with higher risk. Our findings have implications for renewable energy project finance in practice and research.

1. Introduction

An important aspect of cleaner production is the broad usage of renewable energies. The further diffusion of renewable energies requires growing amounts of capital (UNEP et al., 2010), hereby the majority of renewable energy investments is dedicated to project financing to set up energy production facilities: In 2009 large-scale projects claimed 62% of the total renewable energy finance volume (UNEP, SEFI, NEF, 2010).[3] In this paper we focus on financing solar photovoltaic projects (PV, electricity from solar radiation).

PV made up 16% of all new power capacity installations in Europe in 2009 (UNEP et al., 2010). Following the wind sector (with approximately 39% of new capacities), PV is the second fastest growing renewable energy technology (UNEP et al., 2010). Due to its assumed energy potential, accelerating technological progress and fast growing markets for solar applications, PV is often seen as key technology for future energy supply (D'Alessandro et al., 2010). However, whereas the wind industry is already more established, PV is still in an earlier industry stage which provides various uncertainties to investors (e.g. regarding technological standards). Thus, studying investor preferences for PV projects is of particular interest. Financing photovoltaic projects requires two types of capital: debt and equity. Especially third-party lending from banks is important since PV project financing requires significant shares of debt: In 2008 ratios of 80% or even 90% were common (Johnson, 2009; WI, 2010). Given the importance of debt capital, project developers need to understand what drives the willingness of banks to provide funds.

However, current research offers very little detailed information about how debt capital providers evaluate PV projects. Recent contributions underline the relevance of renewable energy in the discourse of cleaner production (e.g. D'Alessandro et al., 2010; Dovi et al., 2009; Sookkumnerd et al., 2007; Kaldellis et al., 2009; Battaglini et al., 2009; Yusoff, 2006; Zuluaga and Dyner, 2007; Nguyen et al., 2010; Narodoslawsky et al., 2008; Klemes et al., 2010; Smyth et al., 2010); discussions so far cover different types of

☆ Note: Assumptions refer to the German legal and regulatory framework as of January 2010. When the survey was conducted, the Federal Ministry for the Environment declared a reduction in PV tariffs by April 2010. Meanwhile, the reduction was postponed to July 2010. Nevertheless, the German PV industry and associated sectors are anticipating significant market changes.

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[3] Non-project investments, i.e., technology development or company expansion, as opposed to project-based asset financing, made up $46 billion or 27% (UNEP, SEFI, NEF, 2010).

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renewable energy production (e.g. Sookkumnerd et al., 2007; Yusoff, 2006; Nguyen et al., 2010), different types of industries (Narodoslawsky et al., 2008; Smyth et al., 2010) or focus on different geographic regions (Sookkumnerd et al., 2007; Kaldellis et al., 2009; Zuluaga and Dyner, 2007; Smyth et al., 2010). But aspects of financing have been discussed only rarely. Given the relevance of such an investigation, this research is set up to better understand drivers of financing clean energy in general and PV projects in particular.

PV projects are characterized by a multitude of parameters such as capacity, module and inverter technologies, maintenance concepts, economic indicators and stakeholder constellations (Grell and Lang, 2008). From expert consultations we know that loan commitments depend on how lenders evaluate project designs from a risk perspective which also includes bank-specific preferences. These are, amongst others, expressed in "white lists" and "black lists" of bankable and non-bankable modules.[4] To better understand debt investors' preferences this paper addresses the following research question: *What kinds of PV project configurations do lenders prefer to finance?* In our research setting we focus on Germany's PV market as it is the world's largest and most dynamic solar energy market.[5] Accordingly, we assume the German project finance industry to be perfectly qualified for such an investigation. As further scope we focus on medium- and large-scale ground-mounted installations subject to the German Renewable Energy Sources Act (EEG) as of 2009, which is the legally binding funding scheme in Germany and which specifies the feed-in-tariffs for different renewable energy sources. Finally, our survey refers to the status quo of 2009 as the German renewable energy policies were revised while our survey took place (January to March 2010). Significant reductions of PV feed-in-tariffs were discussed controversially. Thus, participants were asked to consider the preceding year's market situation in order to have consistent results.

To answer our research question, we have developed an Adaptive Choice-Based Conjoint experiment (ACBC) addressing German experts in renewable energy project financing. Although conjoint experiments are widely used in marketing research (Louviere et al., 2003) and for exploring investment behavior (Clark-Murphy and Soutar, 2004), scholars in renewable energy investment have only just started utilizing this method (e.g. Oschlies, 2007).

As far as we know, our survey is the first exploration of renewable energy lenders' preferences using conjoint analysis. PV project developers may be able to use insights from our research to design projects according to lenders' preferences and thus increase the likelihood of fundraising success. In this way, our results may help in mainstreaming investments in green energy technologies.

We proceed as follows: First, the theory section evolves state-of-the-art knowledge on PV project development. Determinants of bankability are discussed, including financial, technical, political, economic, and stakeholder aspects. Essential project attributes are derived for the ACBC experiment; additionally, different PV business models are designed to be evaluated through market simulations. Second, we introduce ACBC as our data collection method. Our sample and the ACBC and market simulation results are presented. The latter reveals that lenders prefer PV business models with premium brand technology (modules and inverters) rather than low-cost technology – a constant effect that can be observed under variant conditions. We call this "debt for brands". We conclude with a discussion including implications for renewable energy project development practice and research.

2. Research approach

Our study follows an exploratory market research approach. Before applying conjoint analysis it was necessary to examine PV project development practice. Exploratory expert interviews and in-depth literature studies were combined to develop an ACBC experiment for financing professionals. The difficulty was to identify and conceptualize a set of attributes that help in understanding lenders' preferences and reduce real complexities of project development at the same time.

We studied different loan application procedures of relevant institutions, e.g., UmweltBank AG and GLS Gemeinschaftsbank eG and analyzed industry-specific publications, e.g., guidelines, textbooks and journals, dealing with renewable energy project financing (WI, 2010; Grell and Lang, 2008; Boettcher, 2004, 2009; Dena, 2004; Sarasin, 2009; Schwabe et al., 2009; NEF, 2009a,b,c, 2010a,b). Additionally, telephone interviews with financing consultants from different institutions were conducted (UmweltBank AG, GLS Gemeinschaftsbank eG, Windwärts Energie GmbH, and SunEnergy Europe GmbH).[6] The first steps of this iterative process were the expert interviews and parallel literature studies to develop an initial set of attributes. The second step, which started with ten PV project attributes, was a further round of consultations, resulting in a reduced list of six attributes with three, four or five levels each.

Our basic assumption was that these six attributes are essential when banks consider loan applications for PV projects. With regard to individual attribute importance, our research approach is exploratory; i.e., no hypotheses were developed referring to the attributes' individual weights and significance for loan commitments. Hence, the primary objective of the ACBC experiment was to make lenders' decisions more transparent. The essential project development parameters are discussed below.

3. Photovoltaic project development

3.1. Project financing

Project financing is crucial to renewable energies (UNEP, SEFI, NEF, 2010; Grell and Lang, 2008; Dena, 2004; Boettcher, 2009). This financing method has been established for decades for one-time ventures such as infrastructure projects (Vinter and Price, 2006). Three significant characteristics of project financing are often discussed in the literature: first, off-balance-financing, i.e., a financing method separated from individual or corporate books of project shareholders; second, orientation toward future project cash flows, which are the only source of economic performance and security; third, a complex network of project parties and a mesh of contracts to provide for broad risk sharing and risk reduction (Grell and Lang, 2008; Boettcher, 2009; Nevitt and Fabozzi, 2000; Tinsley, 2000). Decisive for project development are the financial strengths and interests of potential shareholders. Scholars appreciate project financing to be a very flexible method (Boettcher, 2009; Nevitt and Fabozzi, 2000). Nevertheless, meeting different shareholders' interests (equity versus debt capital) simultaneously is a challenging task. As there are no universally applicable debt/equity ratios, diverse practitioner literature was analyzed and expert

[4] The term "bankability" refers to the ability of technologies, projects and project developers to attract third-party lending. Bankability is a practical concept used in the PV industry to express the likelihood of fundraising success depending on specific project and actor attributes. Taking the results of our research into account, one might argue that good bankability can result from careful PV project design.

[5] In 2009, the world market for new PV installations had a capacity of 7.2 GW of which 3.8 GW was installed in Germany (BMU, 2009).

[6] http://www.umweltbank.de; http://www.gls.de; http://www.windwaerts.de; http://www.sunenergy.eu.

interviews were conducted to define adequate ratios.[7] For the ACBC experiment, equity shares of 10%, 20%, and 30% were considered to be suitable.

3.2. Technical aspects

The generator is the heart of each PV installation. It consists of a variable number of modules which are made from solar cells based on, e.g., crystalline silicon or different kinds of thin film materials. The modules produce direct current (DC), which has to be transformed into alternating current (AC) by the DC-to-AC inverter, which feeds the electricity into the grid. Another basic component is the mounting system, which has to guarantee stability in cases of stress, e.g., caused by wind or snow. It is sometimes also used as a tracker system to follow the sun. Technical quality is decisive for an installation's performance in terms of effectiveness, efficiency and long-term reliability. Therefore, brands, certificates, producers' track records and long-term experience are quality indicators (Grell and Lang, 2008; Boettcher, 2009).

For technical quality, two generic choices are possible. First, one can decide in favor of technology of superior quality, for which a price premium has to be paid. This option may be referred to as "premium brand". The second option is to save the price premium and use "low-cost" technology (accepting the risk of additional costs due to inferior quality). To enable quality-related choices, a premium brand/low-cost attribute is included.

3.3. System capacity

Capacity is a crucial physical characteristic determining not only financing needs but also efficiencies of scale and thus cost effectiveness. We refer to Lenardič's classification of PV power plant sizes (Lenardic, 2009).[8] For his annual review, he defines seven classes from 200 kWp to 20 MWp and above.

Another clue for attribute construction might be the German funding scheme (EEG). The EEG distinguishes installations which are ground-mounted (lower tariff[9]) from those installed on roofs (higher tariff[10]). For ground-mounted PV plants, a general tariff is applied, that is, the funding scheme does not trigger decisions for specific capacities. It can be assumed that efficiencies of scale generally lead to increasing system sizes. We follow Lenardič's classification in a slightly modified way. This modification is necessary due to mainly two reasons. First, the conjoint methodology requires an even distribution of levels across the different attributes to get optimal results. Second, Lenardič describes classes which do not necessarily represent the categories used by banks. Our expert consultations revealed, for example, that small regional banks finance projects beginning from a few hundred kilowatts up to 1 MW, while big international banks think in 5 MW charges. Thus, our attribute classifies medium- and large-scale ground-mounted PV systems into four categories which conform to methodical requirements and the actual lending practice: 200 kWp–1 MWp, 1 MWp–5 MWp, 5 MWp–10 MWp, >10 MWp.

Table 1
Definition of debt service cover ratio.

Indicator	Interpretation
$DSCR = \frac{\text{Cash flow of Period} + \text{Interest Payment}}{\text{Repayment} + \text{Interest Payment of Period}}$	• Debt Service Cover Ratio • Refers to the ability of debt service on an annual basis

3.4. Quality assurance

Following Grell and Lang, an extensive quality assurance concept is central to applications for loan since constant cash flows have to be secured (Grell and Lang, 2008). The task from a financial point of view is to guarantee rates of return (for sponsors and further equity investors) and debt coverage ratios (for lenders). Instruments include revenue forecasts, performance assessments, inspections, monitoring and operations control.

Inspections and assessments of activated systems are necessary as PV installations face circumstances different from standard test conditions. Such inspections can be enhanced, e.g., by thermal imaging to identify damaged modules, incorrect wiring, or insufficiently calibrated inverters. Quality assurance also requires permanent monitoring and automated operations control to care for actual performance ratios and to recognize malfunctions immediately. Thus, system inspection and system monitoring stand for quality assurance within our survey.

3.5. Economic viability

According to the concept of project financing (off-balance-financing, cash flow-related lending, risk sharing), a project's bankability depends on the project itself and its cash flows; that is, with regard to negotiated recourse project cash flows can be the only security for debt capital providers (depending on type and scale of loan security negotiated by contracting parties: full-, limited-, non-recourse). Therefore, to evaluate a project from a lender's perspective a special indicator is used (Boettcher, 2004, 2009) (Table 1).[11]

Basically, a ratio of 1.0 indicates exact coverage of debt service. If cash flows suffice, the ratio exceeds 1.0; if not, it falls below. DSCR refers to the relation of gross cash flow and debt service on a yearly basis and thus varies with different project phases (Boettcher, 2009). This indicator has to be applied to prevent annual shortages; it is even acceptable to use DSCR alone (ibid). For renewable energy projects, Boettcher as well as Grelland Lang refer to a minimum average DSCR of 1.3; i.e., lenders always charge a minimum contingency reserve (Grell and Lang, 2008; Boettcher, 2004). Practical examples of PV project calculations indicate the possible range as being from roughly 1.0 to 3.0 and above. To create a DSCR attribute we apply three average DSCRs to offer different degrees of bankability (1.2, 1.5 and 1.8).

[7] Mr. Oliver Thominsky (Director of Finance and Administration), Mr.Günther-Störmer (Head of Corporate Strategy), both SunEnergy Europe GmbH, Hamburg, Germany; Ms.Tanja Finke (Head of Project Financing), WindwärtsEnergie GmbH, Hannover, Germany. Interviews were conducted in December 2009 and January 2010.

[8] pvresources.com lists the 1000 largest installations, ranging from 1 to 60 MWp capacity.

[9] EEG 2009 Section 32 (1) defines the tariff as follows: (1) the tariff paid for electricity from installations generating electricity from solar radiation shall amount to 31.94 cents per kilowatt-hour (Note: All tariffs are subject to the digression rules of section 20. The tariffs mentioned are only valid for installations put into operation in 2009.)

[10] EEG 2009 Section 33 (1) structures the tariff as follows: (1) 43.01 cents per kilowatt-hour for the first 30 kW of output; (2) 40.91 cents per kilowatt-hour for output between 30 and 100 kW; (3) 39.58 cents per kilowatt-hour for output between 100 kW and 1 MW; and (4) 33.0 cents per kilowatt-hour for output over 1 MW.

[11] Further coverage ratios are: Loan Life Cover Ratio (LLCR): the focus is on debt service during the life of the loan; Project Life Cover Ratio (PLCR): asks for cash flows during the project's whole lifetime (Boettcher, 2009).

Table 2
Prototypical project initiators.

Initiator type		Reasoning
Owner	Regional utility	Utilities' roles in renewable energy supply chains (in the PV industry in particular) represent one of the most dynamic topics with regard to their future strategies and business models (e.g. AT Kearney, 2007; Accenture, 2008; Frantzis et al., 2008; PWC 2009; Schoettl and Lehmann-Ortega, 2011).
	Multinational utility	Undoubtedly, increasing market shares of renewable utilities will increasingly influence and shape this green industry. Following Boettcher (2009), utilities will soon be important project stakeholders. Lenders might perceive project credibility differently if the utility is an international "big player".
	Financial investor	The US market faces significant shifts in equity investments: "In early 2009, approx. four to six traditional investors remain active [of twenty]. The new deals getting financed are the best projects with solid management teams … New investors could emerge." (Schwabe et al., 2009) Boettcher (2009) assumes similar developments for Germany.
	Vertically integrated PV manufacturer	Initiators often come from the downstream PV supply chain segments (e.g. project developers), but also from related and other industries such as the above-mentioned utilities and financial investors. Recently, market players from the upstream segments (e.g. cell or module manufacturers) have acted as project initiators or sponsors; i.e., they integrate the PV supply chain.
Non-owner	Service provider	This initiator is not an owner of the completed PV power plant. He or she offers a value added service such as project development, consulting, construction and/or installation. He or she can either be specialized in one step in the supply chain or act as an orchestrator (Schoettl and Lehmann-Ortega, 2011).

3.6. Project initiator

The project initiator generates the project idea, identifies further project parties, negotiates, concludes contracts, and thus actively designs the PV value network. He or she can contribute equity capital (sponsor), often acting in concert with a closed-end fund for private and institutional investors (Grell and Lang, 2008). An initiator can play different roles and be differently motivated: He or she may be some kind of investor who is interested in maximizing return on equity, or can also be a service provider. In this case, the initiator's interest is to offer services such as consulting and project development (Schoettl and Lehmann-Ortega, 2011). If utilities set PV projects in motion, their strategic interests may refer to a blend of political, technological and financial aspects. Lenders consider the initiator's background to be noteworthy, since, from a financial point of view, both could have different motivation in terms of interest rates and internal rates of return that have to be synchronized (Tinsley, 2000).

Two categories of project initiators can be defined: those who will own the PV facility and those who will not. Current studies on PV-related value networks and business models consider ownership status as a central actor characteristic (Schoettl and Lehmann-Ortega, 2011; Frantzis et al., 2008). The non-owner group is represented by service providers since their core business is providing construction, installation and other value added project services.[12] Finally, as a result of discussions within the PV industry, four different prototypical initiator types can be identified as potential facility owners (Table 2).

[12] Nevertheless, service providers such as project developers sometimes also invest in projects. Their revenue primarily comes from consulting and local project management activities as well as their exclusive access to specific resource markets (Schoettl and Lehmann-Ortega, 2011).

4. Photovoltaic projects and business models

4.1. From project to business model

The contractual, financial and operational structures among stakeholders constitute a project company ("special purpose vehicle", SPV; Grell and Lang, 2008), which is the predecessor of the operating company. Referring to the PV facility life cycle, it follows that a project, or its SPV, is a bridge to the setting up of an operating company.[13] At the end of the life cycle, deconstruction can also be managed as a separate project (Kerzner, 2009) (Table 3).

In contrast to a regular company, a project is based on a singular, non-cyclical undertaking – in our case the construction of a PV facility. It is limited in lifetime and funding, serves unique project targets and has individual resources brought in by diverse stakeholders (Vinter and Price, 2006; Nevitt and Fabozzi, 2000; Tinsley, 2000; Kerzner, 2009). From an organizational point of view, the project, as "temporary company" (Nausner, 2006), must be distinguished from its successor – the operating company (Table 3). The operating company is an independent, legally responsible and creditable entity, which conducts regular tasks like technical and financial operations and thus secures long-term cash flows. It follows that the initial project creates the basis for cash flows, whereas the operating company handles their long-term realization. In the following, we refer to this approach of value creation and value capture as the essence of every PV business model. *For our research, we broadly define a PV business model as the logic of how economic value is created and captured with a PV facility.*

[13] In Germany, medium- and large-scale installations (e.g. solar parks) are often managed by such operating companies, for example, Solarpark Straβkirchen GmbH & Co KG, which is the operating company behind Germany's biggest ground-mounted PV facility.

Table 3
PV facility life cycle.

Life cycle phase		
Construction	Operation	Deconstruction
Organizational form		
Project (SPV)	Operating company	Project (SPV)

Photovoltaic projects and business models interrelate: Since the initial project defines essential parameters such as facility characteristics and the surrounding value network layout, it also determines the resulting PV business model (Frantzis et al., 2008). Thus, in the project phase the overall business model is explicitly or implicitly shaped. For example, variations of a parameter such as project initiator lead to different approaches of value creation and capture: A financial investor might develop or even realize a PV project in order to sell it immediately, charging a profit margin. In contrast, a regional utility could instead be interested in the technical aspects of integrating PV facilities into its grid (Table 2). That is, different motivations lead to different PV projects and different PV business models (Frantzis et al., 2008). Finally, we can add a crucial task of project development that has been neglected to date: business model design (e.g. Zott and Amit, 2007, 2008; Chesbrough, 2007).

4.2. Photovoltaic business model designs

Based on the identified attributes, different PV projects and business models can be designed. In the disruptive and competitive project financing market, this approach might turn out to be of strategic value. Therefore, our research includes a second investigation: After defining attributes for the ACBC experiment (Table 4), we use these attributes and the empirical findings from the experiment to evaluate different PV business models in a market simulation to discern lenders' preferences for different designs (see "Simulation Results" section).

5. Adaptive choice-based conjoint experiment and simulation

5.1. Method

What kinds of PV project configurations do lenders prefer to finance? To answer our research question we conducted an online Adaptive Choice-Based Conjoint experiment with German bank managers who are responsible for loan decisions for PV projects. In this experiment, we asked the participants to choose from different fictitious medium- and large-scale project proposals based on the set of photovoltaic attributes (Table 4) we had developed. The geographical scope was limited to Germany; participants were asked to consider the German renewable energy legislation of 2009. The online experiment was conducted from January to March 2010.

Table 4
PV business model attributes and levels.

Attribute	Levels
Debt Service Cover Ratio (Average)	1.2
	1.5
	1.8
Capacity	200 kWp–1 MWp
	1 MWp–5 MWp
	5 MWp—10 MWp
	>10 MWp
Brand	Low-cost modules and low-cost inverters
	Low-cost modules and premium brand inverters
	Premium brand modules and low-cost inverters
	Premium brand modules and premium brand inverters
Initiator	Vertical integrated manufacturer
	Regional utility
	Multinational utility
	Financial investor
	Service provider
Maintenance concept	System inspection
	Constant system monitoring
	System inspection and system monitoring
Equity	10%
	20%
	30%

As conjoint experiments have been widely discussed before, we refer to the corresponding literature for an overview (Louviere et al., 2003; Train, 2003). With its roots in marketing research, conjoint experiments are also used for exploring investment behavior (Clark-Murphy and Soutar, 2004; Oschlies, 2007; Riquelme and Rickards, 1992; Shepherd and Zacharakis, 1999). Recently, scholars in renewable energy investment have started to apply conjoint experiments in order to investigate investors' preferences (e.g. Oschlies, 2007). For the first time, this paper investigates debt capital providers' preferences and uses the ACBC tool from Sawtooth Software to perform choice tasks. Having only recently become available, ACBC combines the advantages of the Adaptive Conjoint Analysis (ACA) and Choice-Based Conjoint (CBC) methods (Johnson et al., 2003; Johnson and Orme, 2007).

Compared to CBC, the important advantages of ACBC are "a more stimulating experience that will encourage more engagement in the interview than conventional CBC questionnaires, [the possibility] to screen a wide variety of product concepts, but focus on a subset of most interest to the respondent, [and finally the possibility to] provide more information with which to estimate individual part worth than is obtainable from conventional CBC analysis" (Johnson and Orme, 2007: 7). In providing greater information, ACBC is also especially helpful in cases of small sample size (Johnson and Orme, 2007: 18) and is therefore ideal for this research approach. We analyze the choice results by applying Hierarchical Bayes (HB) analysis, which allows for estimating data on the individual level (Otter, 2007).

The basic idea within choice experiments is that survey participants seek to choose the alternative with the highest utility. Each alternative within the experiment is described by attributes and attribute levels which are the sources of utility (utility of an alternative a: $Ua = Va + \varepsilon a$).[14]

Conjoint experiments display part worth, i.e., values which indicate a distinct attribute's contribution to the total utility of an alternative. In our experimental set-up we ask bank managers to choose from different PV projects which are generally comparable but differ in some aspects – these are our attributes and levels. In the *Build Your Own* section we ask the interviewee to design the PV project he or she would be most likely to finance. In the *Screening* section four different projects have to be evaluated as being "A possibility" or "Won't work for me". In the *Choice Task* section three different projects are presented of which only one can be chosen. Finally, based on participants' choices throughout the three stages, we are able to estimate the part worth they allocate to certain attributes and levels.

5.2. Sample

To compose a unique sample exclusively for this research project, we followed a two-step approach. In a first step we did an online research to map all the banks in Germany that are active in financing renewable energy projects. Within a second step we contacted the banks individually to identify persons who are responsible for renewable energy project financing. Our initial sample for this study

[14] V_a = systematic utility (function of observable variables), ε_a = Random utility component (unobserved influences).

Table 5
ACBC analysis – HB summary of results.

Average Utilities (Zero-Centered Diffs)	Average Utilities	Standard Deviation	t-value
1.2	−5.99	20.90	−0.29
1.5	−1.87	14.70	−0.13
1.8	7.86	17.95	0.44
200 kWp–1 MWp	−33.84	67.15	−0.50
1 MWp–5 MWp	30.77	28.47	1.08
5 MWp–10 MWp	8.40	33.99	0.25
>10 MWp	−5.33	53.72	−0.10
Low-cost modules and low-cost inverters	−93.56	39.53	−2.37
Low-cost modules and premium brand inverters	−18.60	34.59	−0.54
Premium brand modules and low-cost inverters	9.52	28.35	0.34
Premium brand modules and premium brand inverters	102.65	46.03	2.23
Vertical integrated manufacturer	7.21	23.64	0.31
Regional utility	17.74	17.71	1.00
Multinational utility	3.06	20.93	0.15
Financial investor	−20.61	22.71	−0.91
Service provider	−7.41	21.59	−0.34
System inspection	−19.89	20.25	−0.98
System monitoring	−23.43	21.61	−1.08
System inspection and system monitoring	43,32	25.35	1.71
10%	−54.75	46.46	−1.18
20%	31.75	22.28	1.43
30%	23.00	31.57	0.73

consisted of 141 companies. While most of the companies were from the finance industry, the fields of sustainable finance, free financial advisory and renewable energy project development were also represented. We contacted the companies by phone and e-mail to identify individual experts in PV project evaluation. In 55 cases experts could be identified, and in 31 cases they agreed to participate right away.[15] The internet link to the survey and additional information were sent. In February the sample of experts was contacted again via e-mail to motivate the remaining 24 respondents. When the website was closed on 31st March, 43 experts had participated in the conjoint experiment. The sample size is small due to the participants' professional expertise. Nevertheless, this circumstance contributes to consistency and is beneficial for our findings.

Following are some socio-economic data that describe our sample[16]: Within the last three years 28.2% of the respondent companies financed PV projects exceeding €500 Million total volume. A volume of €100–500 Million was financed by another 28.2%. Of the respondent companies, 43.6% financed PV projects with a total volume of up to 100 Million Euros within the last three years. Among the companies, 38.5% operate in Europe. 38.5% operate in Germany, Austria and Switzerland only; 23.1% operate within a global context. Nearly all of the companies have their headquarters in Europe (97.4%). The interviewees work in various positions in renewable energy project financing (e.g. Executive Director Renewable Energies, Head of Project Financing, Project Manager, Structured Finance Specialist). While 43.6% of the respondents have more than 5 years of personal experience in renewable energy financing, 33.3% have 2–4 years, and 23.1% have less than 2 years of experience.

[15] Two aspects were critical to the sample size: firstly, many of the identified institutions are connected in some manner with each other (e.g. different branches of Sparkasse, Sparda Bank, Landesbausparkasse, Hypo- und Vereinsbank) – if one of their branches agreed to participate, others generally refused to; secondly, due to the many requests institutions received from different fields, the invitation to our survey was immediately declined – either for reasons of data security or just to avoid additional work.

[16] Socio-economic data were reported by 39 interviewees; that is, four conducted the choice tasks without answering our additional questions.

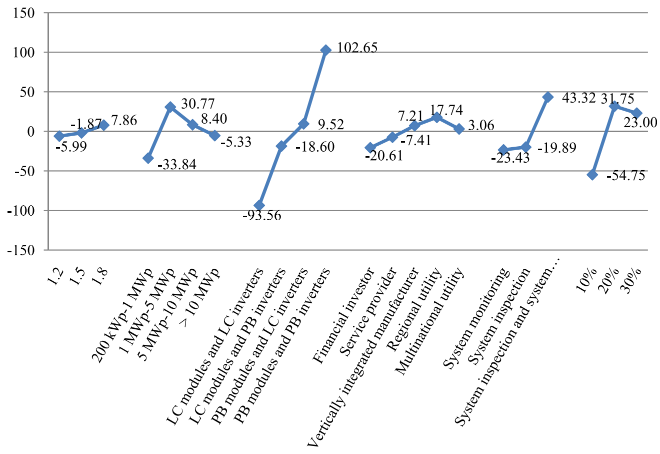

Fig. 1. Zero-centered diffs (attribute levels).

5.3. Experiment results

Our report is based on 1698 choice tasks conducted by 43 survey participants (39.5 tasks per respondent on average). Table 5 displays the interval data of the conjoint results as average utilities based on Hierarchical Bayes (HB) estimates. The relatively high standard deviation reflects the sample size.

By focusing on the values of different attribute levels we gain detailed insight into lenders' preferences (Table 5 and Fig. 1). Positive values indicate positive utilities and thus a positive impact on choices, whereas negative values point to aversion to attribute levels. Overall, lenders favor premium brands. Additionally, they appreciate an all-inclusive maintenance concept with system inspection and system monitoring. Moreover, they opt for project initiators who possibly provide for distribution of generated electricity. Hence, they prefer regional and multinational utilities to be involved in projects. Project initiators such as service providers, vertically integrated manufacturers and financial investors even deter lenders. Regarding capacity we learn that project sizes of 1 MWp–5 MWp are the most attractive, followed by projects with above 5–10 MWp capacity. Small projects of 200 kWp–1 MWp and projects above 10 MWp have a negative impact on choices. Finally, we see an inverted U-curve relationship for the optimal equity ratio peaking at 20% (Fig. 1).

Displaying the results for attributes only (without utilities of the individual levels), we see that DSCR, initially assumed to be the overriding decision criteria, is of lowest importance for lenders' choices. Of superior importance is the premium brand/low-cost attribute (Fig. 2).

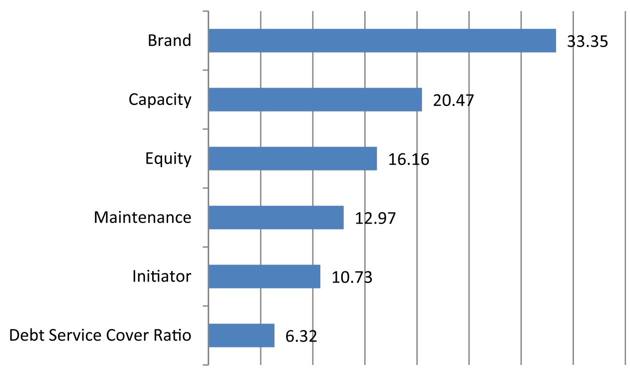

Fig. 2. Average importance of attributes.

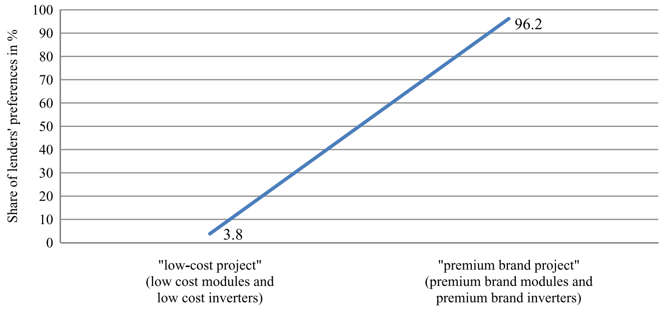

Fig. 3. Results of simulation 1 ("low-cost project" vs. "premium brand project").

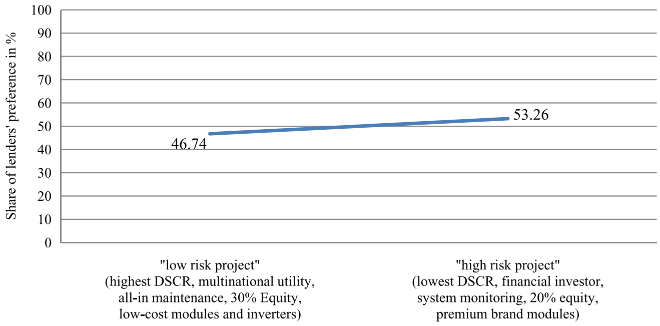

Fig. 5. Results of simulation 3 ("low risk project" vs. "high risk project").

5.4. Simulation results

The empirically derived utility-values allow for the composition of different PV projects and business models. To measure investors' preferences the package from Sawtooth Software offers a market simulator. Each of the following three simulations is based on two different PV projects which stand for specific business model "themes". The following simulation results reveal investors' preferences with regard to different designs (Figs. 3–5).

5.4.1. Simulation 1: Project with low-cost business model vs. project with premium brand business model

In the first simulation we create a project with a low-cost business model and a second with a premium brand business model. Both projects are equal in all attributes (e.g. DSCR, capacity, etc.) but differ in terms of brand. Whereas the project with a low-cost business model has low-cost modules and low-cost inverters, the project with a premium brand business model applies premium brand modules and premium brand inverters. The results of this simulation are unambiguous: Investors by far prefer the project with premium brand business models; 96.2% would choose this project (Fig. 3).

5.4.2. Simulation 2: Project with low-cost business model and high DSCR vs. project with premium brand business model and low DSCR

For the second simulation we also vary the project attribute DSCR in addition to brand. Our initial assumption was that lenders would prefer projects with higher DSCR in comparison to projects with a lower value, since higher DSCR indicates a greater contingency reserve for debt service. In our simulation the project with a low-cost business model has the highest DSCR and the project with a premium brand business model has the lowest DSCR. The result is counter-intuitive: As soon as projects incorporate a premium brand (e.g. premium brand modules), 83.19% of lenders would choose the low DSCR project (Fig. 4). The supposedly rational choice of the project with the highest DSCR is biased; thus, lenders would prefer premium brand business models to those with high DSCR. We call this bias "debt for brands".

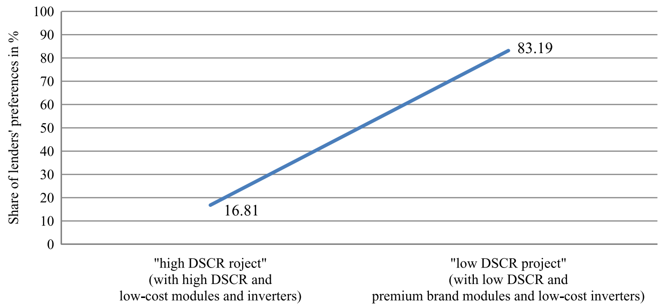

Fig. 4. Results of simulation 2 ("high DSCR project" vs. "low DSCR project").

5.4.3. Simulation 3: Project with low-cost business model, high DSCR and "low risk" vs. project with premium brand business model, low DSCR and "high risk"

In the third simulation, we model both projects in order to additionally account for risk. For the first project, which has a low-cost business model, we ascertain not only the highest DSCR, but also attributes indicating low risk. For that purpose, we define a multinational utility as initiator, which we can assume accounts not only for securities of loan defaults but also promises energy buy-off. Additionally, this project is characterized by an all-in maintenance concept, which reduces the risk of operating failures. Finally, a high equity share serves as additional security. The second project, with the premium brand business model, is configured with attributes indicating a comparatively higher risk (Fig. 5). Our basic assumption for this simulation was that debt investors would prefer the first project as it is of lower risk and promises stronger debt service. However, the third simulation also supports the "debt for brands" bias, as 53.26% of lenders would choose the project that assumes a high risk.

Overall, we find that lenders prefer PV business models with premium brands, even if other attributes like DSCR would lead to different expectations about lenders' choices.

6. Discussion

We find a bias in financing PV projects which we call "debt for brands". Simulations based on our empirically derived results reveal that lenders prefer PV projects leading to business models with premium brand technology rather than low-cost technology. Although we assumed that lenders would always favor project proposals with the highest Debt Service Cover Ratios (DSCR), our study reveals that they also choose inferior proposals with comparably lower DSCR as long as these projects include premium brand solar modules and/or premium brand inverters. Finally, we find that (seemingly risk-averse) lenders would also choose comparably inferior projects, even with comparably higher risk, as long as such projects are developed with premium brand modules and/or premium brand inverters.

Those findings refer to general discussions on the role of brands within business-to-business markets (Homburg et al., 2010). Apparently, brands within PV projects impact lender's decision-making in similar form compared to other decision-making processes between firms.

With that we see implications for a diverse group of practitioners. However, given our exploratory research approach, we frame these implications as suggestions that should be reflected on in the particular context. Based on our results, we first encourage project managers to consider designing PV projects and business models with brands. Even if initial costs for such project types are higher, the price premium for brands could serve as an investment that positively influences lenders' willingness to provide debt capital. Secondly, technology managers, especially those of premium brand technology companies, might want to utilize our findings as selling arguments for premium brand PV components. However, it is still uncertain whether brands within PV projects serve as a signal for unobservable service quality or not (Kirmani and Rao, 2000). Thus, thirdly, we find that debt investors might want to re-evaluate their decision-making process: They should investigate whether it is biased and inferior projects are possibly accepted just because of proposals that integrate brands. Behavioral economics would claim that such biases are a fundamental part of economic decision-making, which challenges the traditional concept of rational choice (Shleifer, 2002; Shefrin, 2000).

We find a main limitation of our work in the experimental set-up of the conjoint method. Experiments always reduce real-world complexities. It can be assumed that other aspects that have not been included might also impact lenders' choices. For instance, behavioral economics refers to group-dynamic determinants of decision-making, e.g. herding. However, we designed our experiment according to expert interviews and conducted pre-tests, and we also provided participants the opportunity to share feedback at the end of the survey. All of the data supported the appropriateness of our experimental setting. Another aspect is that the "debt for brands" effect is stronger than we have had expected. Follow-up research should test the reported bias to ensure that there are no other effects artificially reinforcing the "debt for brands" effect; for instance, we encourage further investigations to test different DSCR scales and to elaborate on certain brands with direct reference to manufacturers.

Aware of these limitations, we would like to offer recommendations for future research. First, our experiment can be a first step toward understanding lenders' preferences for renewable energy projects and business models. Future research may build on that and consider further determinants of decision-making and thus extend our understanding of how banks involve themselves in project financing. Second, drawing comparisons between debt capital providers' preferences from different cultural and policy backgrounds is of interest as understanding such determinants could be decisive in contexts of global project financing. Third, it would be interesting to see whether PV projects with premium brands actually perform better over the years, compared to PV projects that do not cover such brands. Within such analysis insights could be drawn on whether the debt for brand bias results in poor investment decisions or whether it is even of positive impact for investments. Thus, we encourage research to conduct an ex-post analysis to investigate how premium brand business models perform compared to those that apply low-cost technology. Fourth, module brand might be a proxy for certain quality aspects of a project and thus would reduce uncertainty for decision makers. Future work could elaborate on those findings from different theoretical perspectives (e.g. prospect theory, signaling theory etc.) to investigate how these findings extend our understanding of those perspectives. An interesting question for instance from a signaling theory perspective would be why signals that are based on numbers (e.g. DSCR) are inferior to qualitative or maybe even emotion-based signals (e.g. brands). Our results suggest that and elaborate on this question in a context of high uncertainty. However, it would also be of interest, whether there is a tipping point and the impact of different types of signals would change along with the level of uncertainty of the context. Finally, comparisons of whether and how the preferences of project sponsors and project managers differ would be of interest (e.g. in a gap analysis). Identifying ways of bridging differences in preferences and therefore facilitating renewable energy project financing could possibly be based on such approaches. Consequently, further research on project financing and debt capital provision could significantly contribute to the diffusion of renewable energy.

Appendix. Supplementary data

Supplementary data related to this article can be found online at doi:10.1016/j.jclepro.2011.04.006.

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Annex

Publications and presentations related to the doctoral research project

a) Journal articles related to the BMfSI framework (chronological order)

No.	Publication	Addressed BMfSI aspects
1	Lüdeke-Freund, F. & Loock, M. (2011): Debt for brands: Tracking down a bias in financing photo-voltaic projects in Germany, Journal of Cleaner Production, Vol. 19, No. 12, 1356-1364.	- Business model as strategic asset for financing success - Differentiation of premium brand and low cost business models - Financing clean technologies
2	Schaltegger, S.; Lüdeke-Freund, F. & Hansen, E. (2012): Business cases for sustainability: The role of business model innovation for corporate sustainability, Int. Journal of Innovation and Sustainable Development, Vol. 6, No. 2, 95-119.	- Relationships between business case for sustainability and business model - Sustainability strategy and business model innovation typologies - Business model as "business case platform"
3	Boons, F. & Lüdeke-Freund, F. (2013): Business models for sustainable innovation: State-of-the-art and steps towards a research agenda, Journal of Cleaner Production, Vol. 45, 9-19.	- Review of business model literature on technological, organizational and social sustainability innovations - Normative requirements and research agenda for sustainable business models
4	Hansen, E.; Lüdeke-Freund, F.; West, J. & Quan, X. (2013, in review): Beyond technology push vs. demand pull: The evolution of solar policy in the U.S., Germany and China, submitted to Research Policy.	- Comparative multiple case study of Chinese, German and US PV policies - Role of policies and complementary assets for clean technology implementation and diffusion
5	Lüdeke-Freund, F. (2013, forthcoming): BP's solar business model: A case study on BP's solar business case and its drivers, Int. Journal of Business Environment.	- Application of Schaltegger et al. (2012) framework; focus on BP Solar - Re-construction of BP's solar strategy and business model - Identification of BP's solar business model evolution paths

b) Further publications related to BMfSI topics (chronological order)

No.	Publication	Publication type
6	Lüdeke-Freund, F. (2009): Business model concepts in corporate sustainability contexts: From rhetoric to a generic template for "business models for sustainability". Lüneburg: CSM.	Working paper
7	Schaltegger, S. & Lüdeke-Freund, F. (2009): Wie Nachhaltigkeit den Unternehmenserfolg steigert [How sustainability contributes to business success], IO New Management, Vol. 78, No. 9, 12-15.	Practitioner journal article
8	Lüdeke-Freund, F. & Burandt, S. (2010): Universities as learning organizations for sustainability? The task of climate protection, in: Leal Filho, W. (Ed.): Universities and climate change. Berlin: Springer, 179-192.	Book chapter
9	Lüdeke-Freund, F. & Loock, M. (2010): Determinants of credit allocation for photovoltaic projects: Research outline and preliminary findings from conjoint experiments with German financing experts. Lüneburg/St. Gallen: CSM/IWÖ.	Working paper
10	Hampl, N.; Lüdeke-Freund, F.; Flink, C.; Olbert, S. & Ade, V. (2011): The myth of bankability: Definition and management in the context of photovoltaic project financing in Germany. München: Goetzpartners/Colexon.	Industry study
11	Lüdeke-Freund, F. & Loock, M. (2011): What kinds of photovoltaic projects do lenders prefer to finance?, in: Marcus, A.; Shrivastava, P.; Sharma, S. & Pogutz, S. (Eds.): Cross-sector leadership for the green economy. New York: Palgrave Macmillan, 107-124.	Book chapter
12	Schaltegger, S. & Lüdeke-Freund, F. (2011): The sustainability balanced scorecard: Concept and the case of Hamburg Airport. Lüneburg: CSM.	Working paper
13	Schaltegger, S.; Lüdeke-Freund, F. & Hansen, E. (2011): Business cases for sustainability and the role of business model innovation: Developing a conceptual framework. Lüneburg: CSM.	Working paper
14	Lüdeke-Freund, F.; Hampl, N. & Flink, C. (2012): Bankability von Photovoltaik-Projekten [The bankability of photovoltaic projects], in: Böttcher, J. (Ed.): Solarvorhaben: Wirtschaftliche, technische und rechtliche Aspekte [Solar projects: Financial, technical and legal aspects]. München: Oldenbourg, 285-302.	Book chapter
15	Schaltegger, S. & Lüdeke-Freund, F. (2012): The "business case for sustainability" concept: A short introduction. Lüneburg: CSM.	Working paper
16	Lüdeke-Freund, F. & Opel, O. (2013): Die Energiewende als transdisziplinäre Herausforderung [The "Energiewende" as a transdisciplinary challenge], in: Heinrichs, H. & Michelsen, G. (Eds.): Nachhaltigkeitswissenschaften [Sustainability sciences]. Berlin: Springer, accepted, forthcoming.	Book chapter
17	Schaltegger, S. & Lüdeke-Freund, F. (2013): Business cases for sustainability, in: Idowu, S.; Capaldi, N.; Zu, L. & Das Gupta, A. (Eds.): Encyclopedia of corporate social responsibility. Berlin: Springer, 245-252.	Book chapter
18	Schaltegger, S. & Lüdeke-Freund, F. (2013): Von sozialer Verantwortung zu unternehmerischer Nachhaltigkeit: Bedeutung und Ausgestaltung von „Business Cases for Sustainability" [From corporate social responsibility to corporate sustainability: The business case for sustainability concept], in: Keuper, F. & Neumann, F. (Eds.): Sustainability Management: Nachhaltige und Stakeholder-orientierte Wertsteigerung [Sustainability management: Sustainable and stakeholder-oriented value creation]. Berlin: Logos, 51-68.	Book chapter
19	Lüdeke-Freund, F. & Zvezdov, D. (2013): The manager's job at BP: Decision making and responsibilities on the high seas, Int. Journal of Case Studies in Management, Vol. 11, No. 2, 1-32. [plus 18-page teaching notes; also published in French]	Journal article

c) Presentations and conference papers related to BMfSI topics (chronological order)

No.	Presentation / publication	Publication type
20	Lüdeke-Freund, F. (2008): Business models for sustainability: Innovative regional business models as a means of a sustainable change in the energy industry, presented at Oikos Ph.D. Summer Academy 2008 "Entrepreneurial Strategies for Sustainability", 25-29 August 2008, Appenzell, Switzerland.	Presentation
21	Lüdeke-Freund, F. (2009): Business models for sustainability: Innovative regional business models as subject and trigger of a sustainable change in the energy industry, in: Proceedings of Joint Actions on Climate Change Conference & 13th European Roundtable on Sustainable Consumption and Production (ERSCP), 8-10 June 2009, Aalborg, Denmark.	Presentation + conference paper
22	Lüdeke-Freund, F. (2010): Towards a conceptual framework of business models for sustainability, in: Wever, R.; Quist, J.; Tukker, A.; Woudstra, J.; Boons, F. & Beute, N. (Eds.): Proceedings of ERSCP-EMSU Conference 2010 "Knowledge Collaboration and Learning for Sustainable Innovation". Delft: TU Delft.	Presentation + conference paper
23	Lüdeke-Freund, F. & Loock, M. (2010): The role of project initiators' business models for PV project financing: Empirical evidence from choice experiments with debt investors, presented at Oikos PRI Young Scholars Academy 2010 "Mainstreaming responsible investment", 31 January to 5 February 2010, Gais, Switzerland.	Presentation
24	Lüdeke-Freund, F. & Loock, M. (2010): What kinds of PV projects do debt capital providers prefer to finance?, in: Proceedings of GRONEN Research Conference 2010 "Corporate Sustainability, Innovation and Ecosystems in a Globalized World", 23-26 June 2010, Milan, Italy.	Presentation + conference paper
25	Lüdeke-Freund, F. (2010): Welchen Beitrag kann die Geschäftsmodellforschung zur Theorie und Praxis des betrieblichen Nachhaltigkeitsmanagements leisten? [How can business model research contribute to corporate sustainability management in theory and practice?], presented at VHB NAMA Autumn Meeting, 29 September to 1 October 2010, Kassel, Germany.	Presentation
26	Hansen, E.; Lüdeke-Freund, F.; West, J. & Quan, X. (2011): Technology push vs. demand pull: The evolution of solar policy in the US, Germany and China, presented at Academy of Management 2011 Annual Meeting "West meets East", 12-16 August 2011, St. Antonio, Texas, USA.	Presentation given by Erik Hansen
27	Lüdeke-Freund, F. (2012): Die Integration von Umweltstrategien und Geschäftsmodellinnovationen: Konzeptionelle Grundlagen und das Beispiel BP Solar [The integration of environmental strategy and business model innovation: Concept and the case of BP Solar], presented at VHB NAMA Autumn Meeting, 24-25 September 2012, Hamburg, Germany.	Presentation